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PREFACE

This third volume of reprints represents most of the published work done in the Surgical Laboratories of the Department of Surgery and, to a limited extent, in the Presbyterian Hospital during the years 1918 to 1920 inclusive.

Since the appearance of the second volume the Surgical Laboratories have been moved from their former somewhat restricted quarters, into the new laboratory building of the College of Physicians and Surgeons, where there is now provided ample room for increased activities. This move, however, has not been accomplished without protracted delay owing to the chaotic conditions prevailing in the building trades during the past three years, and this factor together with that of the participation of the United States in the World war which called many of our men away, has operated to inhibit the normal expansion of laboratory activities.

These laboratories for surgical instruction, study and research are provided with a record room, technician's room, space for research in chemistry and bacteriology, a library, museum, private offices, an amphitheatre, commodious class operating rooms, animal quarters, and several small, special rooms for supplies, sterilizers and photographer. This surgical unit, occupying 12,000 square feet of floor space, is practically completed and must eventually be permanently cared for financially, possibly by an endowment, to function up to capacity. In the past, its maintenance has been dependent largely upon the kindness and generosity of a donor who has made annual gifts. Because this income, supplemented as it is from several other sources, has only been annual or for short periods of years, it has meant a somewhat precarious existence and necessary curtailment and limitations in laboratory activities in order to meet annual expenses.

This opportunity is gladly taken to again express an appreciation of the generosity of several donors in partially providing for these surgical laboratories, and of the interest of a single donor in their maintenance through so many years.

An extensive investigation was made in these laboratories by Dr. Elbert T. Rulison, Jr., into the "Intra-abdominal use of Dakin's Fluid and Dichloramine-T Solutions, with special reference to local Peritoneal Infections." This was done in connection with his clinical observations at the Presbyterian Hospital, the results of which are recorded in his two papers which appear in this volume. Owing to the bulk of the manuscript and the large number of illustrations it has been impossible to have his third paper appear in a periodical. It is hoped, however, that eventually it will be possible to obtain sufficient funds to have it printed as a monograph.

W. C. CLARKE
Director

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SURGICAL PATHOLOGY *

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THE LACK OF AND THE NECESSITY FOR THE CORRELATION OF SUBJECTS IN MEDICAL EDUCATION

In the study of medicine each decade finds an increase of prescribed courses in the curriculums of the leading medical schools of the country. Not over thirty years ago instruction in pathology was given by the professors of medicine and surgery. The establishment of the chair of pathology was the first step from the custom of many years. Soon the chair of bacteriology was recognized as necessary, and a little later clinical pathology came into being. These topics came into prominence when an increase in knowledge made them too cumbersome for the professor of pathology and his staff to teach, burdened as they were with the constant increase in details in their own department. This increase in topics was not confined to offsprings of pathology alone, but was happening in all the major subjects. In surgery, there are found gynecology, genito-urinary, orthopedic, and oral surgery, all due to a widened scope and knowledge of the parent subject. These branches are well established in the minds of the practitioner and his patients, as shown by their recognition of the specialist, who is simply the ultrarefinement of the surgeon-barber of the sixteenth century. In his endeavor to be the possessor of the latest knowledge necessary for the best results in treatment, the embryo practitioner found that, on account of the unlimited mass of facts confronting him, he must choose one branch and confine himself to it. The medical schools, in the proper performance of their duty, provided instruction and suitable courses in these topics.

In the old days the professors of the various subjects, even of anatomy, were practitioners, each comprehending what every other professor in his medical school was teaching the students. Thus unity of purpose existed, a distinct advantage, in that the medical student from day to day understood without effort the semiclinical lectures and the relations of one subject to another. It must be

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conceded that the simplicity of subjects at the time also led to the same end.

Dating from the Renaissance in the study of anatomy and medicine, laboratories devoted to anatomy first appeared. At that period medical schools existed as establishments in relation to the laboratories of anatomy. As each subject in medical education was born, laboratories for each scientific branch were provided, since there were always scientists, especially in medicine, who desired to investigate things for themselves, as well as those desirous of augmenting knowledge by research. Moreover, in addition to the old-fashioned semiclinical lectures, to afford instruction by personal observations in the rapidly developing topics of medicine, laboratories and their adjunct demonstration rooms, were necessary. With the appearance of laboratories and laboratory workers, akin to pure scientists, on the teaching staffs of the various departments, and because the practitioner-instructors properly continued to deal with clinical subjects, two teaching groups were, unfortunately, formed in each medical school.

Because of this tendency of the scientists, wrapped up in the mysteries of the pathologic laboratory, to slip further and further away from the point of view of the clinician, the medical student is apt to be the sufferer. Many pathologists seem to forget that the majority of students who come before them intend to practice after they graduate. The fact that the individual elects to settle down in the enclosed life of the laboratory, deal in pathology, and teach a more or less abstract science indicates his mental attitude. There are many exceptions to this rule and there have been many in the past; however, it is fair to state that the interests of the pure pathologists are not those of the clinician.

On the other hand, with few exceptions, the clinical professors are out of touch with the laboratory. The countless clinical teachers on the staffs of the many medical schools of the country are not aware of what the pathologists of their individual schools know and teach on a given point. Because of this, the student fails, often until it is too late, to realize that he is studying pathology in order that he may have a better understanding of surgical and medical conditions and processes. The pathology that the student absorbs he is apt to carry in a separate niche of his brain, and his surgery and medicine in others, thus not having the study of pathol-

ogy to assist him to the best advantage in his study of surgery and medicine.

From the point of view of medicine, the instructor in pathology may be presenting to the students gross specimens, among which may be a lung covered by fibrinous exudate. Should the instructor state, "The physical signs the patient has recently shown are as follows . . . and here before you is this beautiful demonstration of their cause," think of the mental picture the student by necessity conjures up when the gross pathologic specimens seem again to be alive before him, as in an actual clinical case. When this point is brought to the attention of the teacher in pathology, he is apt to reply, "That is the duty of the professor of medicine; I am expected to teach the abstract science of pathology." At the same time this teacher of pathology will feel that his domain is somewhat encroached on if the professor of medicine attempts the presentation of specimens to exemplify physical signs. If this deficiency in the teaching of pathology is brought to their attention many instructors of pathology reply, "These are but students; after they become practitioners they will obtain these associations of ideas in physical signs and pathologic conditions." If this be true, does not such an explanation intimate that correlation of ideas is always the best aid in learning? The same clinicians and pathologists will state that this or that prominent man was eminent as a clinician because in his younger days he had unusual facilties for doing necropsies, especially on the patients whose physical signs he had known from personal observation. Others may contend that these men possessed superior mental talents. Possibly so; but they directed their talents so that the point in hand was attacked from every possible side.

From the point of view of surgery, a clinical instructor in the routine of surgical teaching may present to the students a suppurative arthritis. At a remote period the pathologic staff of the school discourses in a purely abstract manner on the changes following the repair of abscess cavities, and possibly may mention that abscesses occur in joints. To return to the clinical aspect, the surgeon expounds on the necessity for drainage of the joint to limit as far as possible the toxemia; he may state that the usefulness of the joint will probably be more or less impaired, even speaking of adhesions and the separation of the cartilages. The average student cannot bridge the gap and visualize the actual pathologic

changes, logically thinking over the abstract teachings gleaned in the department of pathology. The pathologist, with the almost countless themes that must be covered in the allotted time, cannot pause to mention physical signs, clinical course, and the treatment necessary for each pathologic condition and process that is touched on.

The surgeon, on the other hand, with his mind riveted day after day on the purely clinical side, his time taken up with clinical duties, cannot be expected to give in detail and discuss at length all the vagaries of the gross and microscopic changes occurring and likely to occur from the day of the infection of the joint until healing is complete and the process has reached a quiescent stage. How may such a lack of correlation in teaching be compensated for?

THE RÔLE OF SURGICAL PATHOLOGY

So far as surgery is concerned, the subject, surgical pathology, should be the connecting link in the student mind between surgery and pathology, in order that the student may readily correlate each point as it is presented. Surgical pathology is really a study of the clinical aspect of the pathologic conditions and processes coming directly under the notice of the surgeon, and not matter abstracted from the domain either of pathology or surgery. Surgical pathology, for example, should show the student how a given physical sign in a clinical process may be explained if the pathologic condition is understood.

The importance of this correlation of ideas for the medical student is not universally realized, nor is there any general comprehension of the rôle that surgical pathology should fill in medical education.

THE PERIODS FOR SURGICAL PATHOLOGY IN THE STUDY OF MEDICINE

Surgical pathology should commence as an introduction to surgery and its special branches, at the period when the student is well advanced in his study of introductory subjects, such as gross and microscopic anatomy, physiology, and physiologic chemistry, and at the time when he commences bacteriology and pathology, in order that these given subjects shall be studied side by side. This period is usually reached some time during the second year at the medical school. To round out his

surgical course to the best advantage, moreover, surgical pathology should be reviewed in the last year. In the student's introduction to surgery, the subject, at best, is a new field in his education, but after he has had a period of time to correlate whatever he remembers, after he has seen considerable clinical material, attended many operations and followed their subsequent clinical progress, and heard lectures on surgery, he will grasp the subject from a much broader point of view.

TIME TO BE DEVOTED TO THE SUBJECT

To make a lasting impression on the student mind, the introductory course must extend over a considerable period. At least three hours a week throughout the year are necessary, of which two one-hour sessions may be devoted to discussion in the class-room, and one hour to laboratory work or clinical observations.

In the second period, two two-hour sessions of laboratory work for a quarter of the year are sufficient. This time may be evenly divided between the laboratory of the university hospital to facilitate instruction in human tissues, and the college laboratories of surgical pathology.

COURSE IN SURGICAL PATHOLOGY; TOPICS FOR STUDY

The student, during his first period, should read the given lessons in a text-book on surgery and study the pathologic processes in a text-book on pathology; this should be followed by conferences with the instructor, combined with laboratory work and the observation of clinical material.

The course should commence with one of the simplest possible processes and conditions that are departures from the normal, such as a simple injury; for example, an incised wound. The study of this will lead the way to all the interesting phases of repair, bringing in the more and more complicated forms of injury involving the various tissues of the body—skin, connective tissues, mucous membrane, muscle, bones, nerves, vessels, and the parenchyma of the various organs. The student has an opportunity to learn just what the injury does to the living tissues and to observe the pathologic processes and conditions that supervene. The discussion in the class-room must of necessity cover a wide range—gaping of the wound, hemorrhage, exudate (coagulated or fluid), proliferation of tissues, clinical terms, regeneration and repair, ideal, delayed and abolished healing, inflammation, infection, scar tissue, and the interference with function. In other words, much more than the actual

study of the repair of an incised wound must be touched on by the students.

Attention is here called to the fact that inflammation as a topic has not been mentioned. It seems to make more impression on the students and to be better understood if the process is treated merely as an incident in all injuries, varying simply in degree. Confusion is thus avoided to a certain extent in the student mind between what the clinician understands by inflammation and what the pathologist teaches.

Under supervision, in the laboratory, a student may make a small incised wound in an anesthetized animal. The entire student section may see the wound gape, and the clinical changes presenting various physical signs may be followed to the termination of the process in repair. Microscopic sections, taken at the various stages of repair following the injury or operative wound, from both animal and human tissues, will serve to illustrate and furnish a basis for discussion of the physical signs and actual pathologic processes present. The physical signs must be considered with special reference to the pathologic conditions that produce each sign. The clinical course observed from day to day affords an opportunity to discuss the consequent change in the pathologic conditions. Coincidental variations in the physical signs must be dealt with at length.

To emphasize the rôle that infection plays, a hypothetic injury should be discussed from which all outside irritants may be excluded. In this way the cellular changes pure and simple, due to the injury alone, may be learned. The introduction of a hypothetic "non-irritating foreign body" into the tissues may be studied. The cellular reactions in such an experiment may be contrasted with those that occur in the presence of an "irritating foreign body" or one that carries various chemical elements into the tissues. This paves the way in the student mind for an understanding of the complicated and varied reactions of the living animal tissues in which infections are present, especially surgical infections. Comparisons may be constantly drawn between the hypothetic simple wound, a wound containing a "non-irritating foreign body," and, finally, an infected wound.

All the possible terminal phases of the surgical-pathologic process should be pointed out in detail, since these suggest what various forms of treatment might avail. It is not the idea that the treatment, as such, is to be taught, though to lose sight of treatment is a bad begin-

ning for the medical student. His great rôle in afterlife, aside from attempting to prevent pathologic processes, is to treat them, and that he cannot treat intelligently unless he understands as much as possible, should be instilled into his mind. This attention to treatment, by necessity not touched on by the instructor in pathology, is one of the many little things that tend logically to connect, in the student's mind, pathologic matters with the clinical features of medicine and surgery.

In addition to the study of injuries and the repair of the various tissues compromised by the so-called surgical infections, a consideration of the special infections, such as the surgical aspects of tuberculosis, syphilis, anthrax, glanders, tetanus and hydrophobia, should also be included, and the surgical terms, cellulitis, abscess, furuncle, carbuncle, toxemia, septicemia, erysipelas, aneurysm, ulcer and gangrene, should be defined and explained. The study of diseases and injuries of anatomic structures, such as vessels, bones and joints, including synovial membranes of tendon sheaths and bursae, and the clinical-pathologic aspect of tumors, must also be covered at length.

Some time must be spent in discussing a normal as contrasted with a pathologic individual who has been subjected to an injury. The rôle that vascular changes and disturbances of metabolism play in the formation of ulcers and in gangrene must be emphasized. The bearing that the common constitutional diseases have on infections and the repair of operative wounds, is also important. For the sake of discussion, an operation of election on a simple hernia, restrained by a truss, in a person under 40 may be chosen. The question is whether or not such an operation shall be done on a person who has chronic nephritis, a heart lesion, diabetes or pulmonary tuberculosis accompanied by cough. Next may be considered an operation on a patient with the same conditions, for a simple inguinal hernia too large to be restrained by a truss; to make the problem complete, a strangulated inguinal hernia, an operation of necessity, should be mentioned. The advisability of operations on pathologic persons should be discussed, regarding not alone the repair of the wound, but also the effect of the anesthetic on organs of absorption and of elimination, the shock of the operation, and the elimination of tissue toxins.

In the second period, when the students meet the instructor in surgical pathology, best in the students'

fourth year, very general topics should be taken up. Pathologic material from patients whom the students have seen both clinically and at operation serves well as a basis for discussion. For example, observation of coagulated exudate on the peritoneal coat of an acutely inflamed appendix will lead into the general topic of adhesions, peritonitis, the significance of coagulated and fluid exudates found at the time of operation and their relation to the prognosis. Microscopic sections may also be shown of the same appendix covered with exudate. At the time, sections of adhesions from other conditions indicating different characteristics may be on exhibition.

If there is in the given medical school a course in surgical technic, in which animals are used as subjects, the possibilities in teaching surgical pathology become almost limitless. It is of great advantage for the students to see for themselves the repair of tissue in common abdominal operations, in which healing has been almost ideal. Necropsies in operative abdominal conditions in man are always made under circumstances of peritonitis or some other unfortunate pathologic process. On very rare occasions, the surgeon, because of the necessity for a subsequent laparotomy, chances to see the result of his primary operation. Every surgeon realizes how infrequently these opportunities occur. By necropsy of animals that are making a good recovery as early as thirty hours, and at later intervals, after operation, the students may be shown the suture line of an intestinal anastomosis. Attention may be called to the integrity of the abdominal wall, and practical demonstration may be made of the stress the healing wound will withstand. Pointing out the errors in technic, such as resulting hemorrhage, intestinal leakage with the subsequent peritonitis, and excessive narrowing of intestinal lumen owing to too great invagination of intestinal wall at the time of suture, impresses the students with the importance of guarding against these dangers. This affords the students actual demonstration of the ideal and pathologic conditions that will obtain in similar circumstances in human abdominal cases shortly to be cared for by them as hospital interns.

METHODS OF INSTRUCTION

In teaching surgical pathology, the instructor must decide whether he shall be dogmatic or shall constantly indicate that there are but very few facts and that much

is theory or hypothesis. Certain instructors believe that they undermine the confidence of the students both in their teacher and in medicine if they continually point out that there are many differences of opinion. Others state that students are not capable of judging or deciding for themselves if given several hypotheses attempting to explain a clinical phenomenon.

These two points of view are obviously short-sighted. As to the first, there is always repetition in teaching, and since several instructors may present to the students their opinions, failing to state them to be but their opinions, the students, when they confer together, as they are bound to do, find that the several statements are at variance. Naturally there is confusion, and their confidence in their several instructors is certainly undermined—just the thing each teacher sought to avoid by being dogmatic.

The second point of view, that the student cannot discriminate, is certainly vicious in itself. In the classroom the student may be blamed for not being able to think; and often as not (as an expedient) he is not allowed to; but, in the first clinical case that the student deals with, the instructor expects him to think and reason both in diagnosis and in treatment. Certainly the embryo physician must often use his wits, and the earlier he commences the better.

A medical student is a postgraduate student, and it is the duty of the instructor to state frankly what is fact and what is theory in discussing any phenomenon. If the instructor so elects, he may state his personal opinion of which is the best theory, assuring himself that the student understands it to be merely an opinion. The discussion of the instructor's opinion tends to widen the student's horizon, to fix the subject in his mind, and to encourage him to think. Many instructors will be disturbed by the free expression of a student's ideas, but it must be realized that in a class of seventy or eighty men many types are present. Their manner in meeting the instructor varies widely, depending on their early environment and education. All these differences must be allowed for by the instructor.

The main thing is that the instructor must realize that he cannot teach unless the student is willing to learn, and the more the instructor leads the student to reason, however skeptical he may be of the student's ability, the better teacher he is.

It must be realized by the instructor in surgical pathology that his subject is far from being a mathematically exact entity. There is but little that the student may learn by rote. And in the student's entire education, even though he be a college man, there are but few subjects that touch on a wider range of sciences than surgical pathology. Because of this, one of the simplest rules of teaching must constantly be borne in mind; that is, to be always informed of the student's conception of each subject from day to day. Simple questioning of the student, the ordinary method of instruction, is not sufficient. Leading the student into discussions and into asking questions concerning the physical signs and pathologic conditions instantly informs the instructor of the progress the individual student is making. Any one may make a seemingly clever answer, but it takes a well-oriented student to ask a sensible question.

Frequently by the very token, as stated, that surgical pathology, its teachings and the fundamental principles dealt with, are far from mathematical entities, it is difficult for the students to realize the wide variations in the physical signs, clinical course, symptoms and pathologic processes and conditions of even type diseases. They may read a given text description of a disease, pneumonia for example, and possess a fair working idea of the morbid process, be able to answer questions with reasonable intelligience, and fail miserably in diagnosis. The given clinical case did not happen to fit the typical text-book description which the students had read. On the other hand, the students do not fall into this pit of a case if presented to them by the clinician. The students realize that this given patient chances to present this or that peculiarity. They also realize that the next case of the same disease may present other peculiarities. When teaching was almost entirely clinical, as in the past, this very fact made the study of type diseases somewhat simpler, although they were less understood. The students read up the theory of the disease subsequent to each clinic and appreciated the similarity of points found in the text and those shown in the clinic. If these clinics are not given in the course of surgical pathology, each student of the class will have a different mental picture of such a condition as an infected wound, for example. The composite of the entire class would likely possess a very good concept of infected wounds, though the ideas on the subject of any one student would not be at all satisfactory.

This may be tested out in a simple manner for the purpose of informing the instructor and for a demonstration to the students to show the students not so much what they do not know as the pitfalls in their path and how they may be avoided. The written descriptions of an infected wound obtained from each student may be compared before the class. The instructor may describe to the students any infected wound that occurs to him and ask them what he has been talking about. An infected wound may be presented in the clinic and the instructor may ask each student in turn, "What is the pathologic condition?" He will be amazed and pained at the dissimilarity of the written descriptions, surprised to learn that but one or two recognized the condition he has described and be shocked to hear but two or three mention the correct pathologic condition. An instructor's first impulse is to complain of the ignorance of the students and to exclaim that they will never learn anything. He must, however, realize the root of the trouble and demonstrate the matter to the students, letting them see for themselves that they must appreciate the wide range of possibilities for injuries and disease and must also bear this in mind when reading from text-books. The students must be brought to see that if an infinite number of pathologic processes and conditions could be observed, every possible variation would be exemplified. For convenience in classification and for description, mile-posts along the clinical and pathologic road have been selected as types and have been given the various familiar clinical and pathologic names. By necessity there are pathologic conditions and processes not occurring at a mile-post, but nearer one than another; from such a mile-post will the process or condition receive its name.

Certain students readily grasp these facts and easily outstrip their companions in the study of surgery; while others, possibly those who have excelled at college in the classics, fall behind and never even reach the plane of apparently much poorer men. This often tends to discourage many who before have had no trouble as students, but cannot properly correlate the knowledge necessary to thoroughly understand the complex biologic facts that exist in living tissues from the time of the incident of an incised wound until its healing is complete.

CONCLUSION

Since surgical pathology shall bridge for the students the wide gap between pathology and surgery, the instructor should be trained as a clinician, and, in addition to being a person with interest in clinical matters, he must at the same time spend many hours in the laboratory, studying both the gross and microscopic aspect of specimens from surgical conditions. Regarding these specimens, strict attention must be paid to the clinical course, the physical signs presented, and the outcome following operations or other treatment. Constant experimentation, involving the fundamental principles of surgery, should also be conducted, in order that, so far as possible, the instructor's knowledge of his subject shall be from his personal observations.

The surgical pathologist is to directly connect the thoughts of the student with the pathologic aspect of surgical conditions; he can therefore best serve his purpose in such a rôle by being an integral part of the department of surgery, making his associations more intimate with the teaching staff of surgery. Thus the surgical pathologist has more direct access to clinical material, and with the laboratories now supported by the department of surgery in many medical schools, facilities to study pathologic material are available. The association of the surgical pathologist with the clinical staff of the department of surgery is also by this means made more intimate; the laboratories of surgery become a clearing-house, as it were, of the clinician for his surgical material. Because of this, the clinical aspect of any concrete clinical condition, by discussions with clinicians, is kept fresh in the mind of the surgical pathologist, and he is not led away by the more or less philosophic and abstract point of view of the pure pathologist.

The field of the surgical pathologist is an exceedingly interesting one because of its concentration, enlivened by the clinical aspect, enriched by facts gleaned from microscopic examination of clinical material obtained at operation and constantly reviewed in the subsequent clinical course. Surgical pathology should introduce to the students fundamental surgical principles and prevent any separation of ideas and concepts of both normal and pathologic processes and conditions as taught in the departments of anatomy, pathology, bacteriology, physiology, physiologic chemistry and of surgery in medical education.

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FASCIA TRANSPLANTATION INTO VISCERAL DEFECTS

An Experimental and Clinical Study

By HAROLD NEUHOF, M.D., New York City
From the Department of Surgery, Columbia University, College of Physicians and Surgeons

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FASCIA TRANSPLANTATION INTO VISCERAL DEFECTS

An Experimental and Clinical Study[1]

By HAROLD NEUHOF, M.D., New York City
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Introduction

AFTER the principles of free fascia transplantation had been established, chiefly through the pioneer work of Kirschner, fascia grafts were soon employed for a great variety of purposes. Many conditions offered possibilities for correction by fascia transplants, and a considerable number of cases of successful clinical and experimental transferences into *aseptic* fields have accumulated in the literature. These studies have not definitely settled the ultimate fate of transplanted fascia, but they have demonstrated clearly that, for practical purposes, fascia is a remarkably satisfactory tissue for transplantation.

A field absolutely free from the likelihood of infection and rigid asepsis at operation, have always been considered absolutely essential for any successful transplantation. It was, therefore, expected that attempts to transplant fascia into *non-aseptic* areas would fail. A few successes and about an equal number of failures, both clinical and experimental, have been reported. Thus, fascia transplantation into unaseptic fields was considered very unreliable, and was practically discarded. From a survey of the subject, however, I believed that the question had not been investigated sufficiently. Above all, it appeared of great interest, from the practical as well as the experimental side, definitely to determine if fascia can be safely and satisfactorily employed for bridging defects in hollow viscera. This aspect of the subject was especially considered in the work on fascia transplantation, carried out in the past two and one-half years, and will be particularly dwelt upon. Its practical significance will appear in the descriptions of experimental groups, and in the presentation of two cases, one of tracheal and one of urethral defect, to be given at the close of the paper.

Most of the experiments to be reported are devoted to the types of fascia transplantation that have hitherto failed or have not been attempted. For the purpose of arriving at a well-balanced conclusion, the failures as well as the successes will be emphasized.

The Advantages of Fascia as a Tissue for Transplantation

The free transplantation of fascia is only a small part of the whole subject of tissue transplantation. There are many conditions for which fascia transplants, in contrast to transplants of other tissues, would be undesirable or could not be employed. When Kirschner first reported his work, he believed the procedure to be of limited practical application and value. He was led to employ fascia as a substitute for tendon defects be-

[1] Awarded the Biennial Prize for 1916, of the Alumni Association of the Columbia University, College of Physicians and Surgeons.

cause the quantity of tendon material that could be grafted autoplastically was very limited, and because fascial tissues are so remarkably similar, in anatomic structure, to tendon. Since Kirschner's publication, the practical uses that have been made of fascia transplants have multiplied rapidly. It is, therefore, pertinent to inquire into the advantages of transplants of fascia over transplants of other tissues for conditions in which, up to the present time, the latter have been employed or suggested. In this inquiry autotransplants alone will be considered.[1]

Numerous experimenters (Kirschner, Davis, von Saar, Valentin, and others) have demonstrated that fascia transplants usually heal in place with practically no changes in the fascia or in the adjoining tissues. This holds true not only when the parts are at absolute rest, but also when the transplant is under tension, or is altered in shape and position with the changes in the organ to which it has been transferred. These experimental observations have been supported by a number of corresponding ones in the human being. Indeed, the tendency of transplanted fascia to heal in place must be extraordinarily great to account for results encountered not only in simple cases, but also when the conditions were thought very unfavorable for the success of any transplant — poor blood supply in the region of the graft, nourishment possible to only one surface, etc. An analysis of the reported cases shows that there have never been any undesirable manifestations as a result of transplanting fascia into aseptic fields.

Without entering into the vexed question of the ultimate fate of transplanted tissues, one may say that, as far as fascia is concerned, it has not been definitely settled. The reason for this lies in the inadequately elapsed time of observation after fascia transplantations. Within the limited period, however, most experimenters find that few, if any, significant changes are seen in the characteristic structure and staining qualities of transplanted fasciæ. Some have noted œdema of the transplant soon after transference. Its viability does not appear to have been affected as a result, except when, very rarely, the primary swelling was too great (von Saar). Concerning the fate of transplanted fascia in the human being, most of the examinations have been made relatively soon after operation, and the fact that transplants have been found viable is no evidence of their final condition. In this connection the more prolonged observation in a case reported by Denk is of interest. He examined a sheet of fascia 11 months after its implantation into a dural defect. The transplant was transformed largely into dense fibrous tissue, apparently as the result of its gradual disintegration with simultaneous connective-tissue replacement. It is therefore evident that the fate of transplanted fascia is not known, and that the probabilities are in favor of its ultimate death. From the practical side, however, the question does not appear to be of any great importance. There is no reason to believe that the sheet or strip of good firm tissue that may finally form, functioning as the original transplant, is less serviceable than living fascia.

In comparing autotransplantation of fascia with that of other tissues — fat, muscle, skin, peritoneum, periosteum, etc. — its practical advantages are at once evident. Besides its great tendency to heal in place, fascia requires minimal blood supply for its nourishment. It is always very readily obtainable and, a factor of great importance, in almost unlimited quantities. Fascia has great tensile strength and, at the same time, shows very little tendency to stretch or to shrink, under ordinary circumstances. Lastly, it is easily adapted to the surfaces of any organ. None of the other tissues suggested or used where fascia is applicable, has all these characteristics. Those approaching nearest are peritoneum (when resistance to tension is not required) and periosteum (when resistance is required). Kolaczek urged the use of transplants of peritoneum for a number of conditions because it is lined by smooth mesothelium. The perishability of mesothelial cells is very well known; in fact Kolaczek could not demonstrate that they remained

[1] The arguments here advanced represent, in the main, the views held by Kirchner, Kleinschmidt, and others. In some respects they have been modified to conform with opinions I have formed from personal experiences and from analysis of many reported studies.

alive when the peritoneum was transplanted. Furthermore, the applicability of peritoneal grafts is very limited and the sacrifice of large sections of peritoneum is certainly not harmless. Long, narrow strips of periosteum from the subcutaneous surface of the tibia are almost as readily obtainable as fascia. If, however, long wide sheets are required, the deeper surfaces of the tibia must be exposed. This is objectionable because it requires considerable dissection. Should an infection of the wound occur, the complication is far more disagreeable than an infection of the subcutaneous wound after the removal of fascia. Finally, periosteum is not as plastic as fascia, does not hold sutures as well, and probably retains its structure for much shorter periods.

It is hardly necessary to direct attention to the importance inherent in the fact that the transplantation of fascia can invariably be autoplastic, for the many advantages of autoplastic over other types of transplantation — greatest probability of the transplant healing in place, guarantee against transmission of infection, etc.— are now generally agreed upon.

The Clinical and Experimental Uses of Fascia Transplants

To obviate the impression that fascia is universally applicable as a transplantable material, attention was called to the fact that there are many purposes for which it is undesirable or inapplicable. The clinical and experimental uses to which fascia transplants have been subjected, or for which they have been suggested, will now be considered.

1. Fascia transplants into aseptic fields

A critical analysis of all the results will not be attempted. This has been made by Kirschner, Kleinschmidt, and others, and the advantages of transplantation of fascia over ordinary surgical measures for many affections have been pointed out. I shall take up certain applications in detail in the sections devoted to additional work in such fields. However, a brief survey of all reported applications is desirable, as an index of what has already been accomplished. Fascia has been employed either in the form of sheets or of strips.

Sheets of fascia have been used (1) to fill gaps at operations for hernia, especially umbilical, postoperative, and recurrent. Very many satisfactory results have been obtained, especially when the usual procedures might have been expected to fail because of very large defects, poorly nourished cicatricial tissues, etc. Up to the present time, no failures have been recorded after the use of fascia. (2) For defects of the cranial dura. The procedure has been found remarkably satisfactory in more than 80 reported cases, and has been demonstrated to be free from danger. The fascia heals in place without reaction and almost invariably makes a water-tight closure. (3) For thoracic defects. The few recorded results have been excellent. The details will later be considered. (4) For wounds of solid organs. Large bleeding areas in the liver have been satisfactorily covered by fascia in several instances. It has been suggested for wounds of the spleen and kidney; in the latter case the possibility of extravasation of urine would militate against its use. Fascia transplantations into wounds of the lungs as well as of the liver will be taken up later. (5) For isolation of nerves with the object of preventing fresh adhesions after nerves have been freed from beds of scar tissue. It has been shown, however, that adhesions between nerve and transplant may occur. (6) For reinforcement of blood-vessel sutures and for occlusion of aneurisms. Experiments have demonstrated that sheets of fascia are strong enough to maintain stenosis of large arteries. Clinical experiences have not as yet been reported. (7) For defects of the diaphragm. Some experimental successes and failures have been reported. The question will be discussed later. (8) For interposition in ankylosed joints and for replacement of joint-capsules. A few enthusiastic clinical reports have appeared, but the advantages of the procedure over those ordinarily employed have not been clearly demonstrated.

Strips of fascia have been used: (1) Most frequently to replace or to reinforce ligaments, tendons, or paralyzed muscles. Only a few

of the many satisfactory clinical applications need be mentioned. Defects of tendons have been replaced; the correction of certain paralytic deformities of the shoulder and foot, of habitual dislocation of the patella and of the shoulder, has been successfully practiced; fixation of the "winged" scapula has been accomplished; ocular ptosis has been corrected, etc. (2) To suspend the movable kidney in its corrected position; to anchor the testicle in the scrotum in operations for cryptorchidism. It has been suggested for ptosed liver and spleen. Very few cases have been described. Not all were successful, and one cannot as yet say that the procedure has been placed upon a sound basis. (3) For suture of fractured patella, with the purpose of eliminating the use of foreign material. For the same reason, as well as for its great strength, sutures made of strips of fascia have been suggested for hernia operations. (4) To occlude the pylorus. Some satisfactory clinical results are reported, the operation having been based upon a number of experimental studies. I have shown elsewhere, however, that the experimental grounds for the operation are unsound. It was found that previous experiments had not covered sufficiently long postoperative periods. The conclusion I arrived at after more prolonged observation was that pyloric occlusion did not occur regularly after ligation with fascia strips, and was almost invariably very brief and incomplete when it did follow.

II. FASCIA TRANSPLANTS INTO AND ABOUT THE HOLLOW VISCERA

The very few efforts that have been made to transplant fascia in these regions are based chiefly upon the studies of Koenig and of Hohmeier. The former, in a series of experiments carried out in 1911, reported that leakage did not occur after fascia reinforcement of weak suture lines in the incised œsophagus, stomach, intestine, and bladder, when leakage might have been ordinarily expected. Koenig applied the method in several operations upon the human being, with results that were not always satisfactory. Nevertheless, on the basis of his experiences, Koenig advocated the use of fascia for such purposes. Hohmeier, in his experiments, went one step further; he attempted to bridge complete defects of the bladder, œsophagus, and trachea, by fascia sheets. His work is the source of statements in the literature to the effect that fascia has been transferred successfully into such defects. The unsatisfactory outcome of Hohmeier's experiments, especially in transplants into vesical defects, will be subsequently indicated. Kostenko and Rubaschew, as well as Joffe, demonstrated in a large series of experiments that it was in most instances essential to preserve the continuity of the mucous membrane of the hollow viscera in transplanting fascia over them. All these studies will be considered in greater detail. I wish to point out here that the only grounds for the rather generally held impression, that the various hollow viscera have been successfully "patched by fascia" experimentally, are the reports of very small tracheal and œsophageal defects that have been treated in this way. There is a single instance of successful fascia transplantation into a defect of a hollow organ in the human being. This is a case of tracheal fistula, reported by Levit, which will be described later. An unsuccessful attempt to bridge a urethral fistula by fascia comprises the only additional effort in this field.

On the other hand, Koenig's results in the *reinforcement of suture lines* in the bladder led to similar successful attempts by other surgeons. These will be sketched very briefly. Schmid reports a vesicovaginal fistula operated upon several times without relief. He closed the opening in the bladder, sutured over it a piece of fascia 2 x 3 centimeters, and approximated the freed flaps of cicatricial vaginal mucous membrane. Smooth healing followed. In several instances, Bumm succeeded in supporting large vaginal prolapses by implanting fascia sheets under the mucous membrane between the pubic bones; his report, however, was made shortly after the operations were performed, and the final results are unknown. Henschen was the first to employ supporting strips of fascia in a case of rectal prolapse; the result was perfect, despite some suppuration in the wound

and partial exposure of the transplant. His method was successfully modified by Juracz and by Brun. From these reports conclusions entirely favorable to the practical use of fascia transplants about the hollow viscera would naturally follow. It should, therefore, be stated that sloughing and necrosis of the transplanted fascia occurred in all the reported cases other than those above mentioned — fascia rings about sacral anus after resection of the rectum (Enderlen, Kirschner), fascia over end-to-end suture after resection of intestine (Koenig), fascia over sutured urethra (von Hacker, Hohmeier, Koenig), and one case in the four fascia transplants reported by Bumm.

III. FASCIA TRANSPLANTS INTO INFECTED FIELDS

Closely related to the question discussed in the preceding section is that of fascia transplantation in the presence of infection. This aspect of the subject has received very scant attention. Yet an analysis of some of the reported experiments indicates that necrosis of fascia transplants need not necessarily occur when the field becomes accidentally infected. In fact, several experimenters (Davis, Kornew, Hirano) noted this; Davis remarked that "the transplanted fascia seems particularly resistant to infection for it retained its structure despite sloughing of the surrounding tissues." There are a few clinical reports of fascia having been deliberately transplanted in the presence of infection. Although no general conclusion can be drawn from this very small group of cases, they are of interest in connection with the work to be reported and will therefore be given in detail.

Kirschner. Radical operation for vesical extrophy. A defect 10 x 12 centimeters of the entire abdominal wall, soiled by urine and fæces, remained. The sole closure of this infected gap was the transplanted fascia. The skin and subcutaneous tissues could not be entirely sutured over the transplant, the latter being exposed over an area 4 x 10 centimeters. Despite these conditions, necrosis of the fascia did not occur and a hernia did not develop. Death from pyelonephritis supervened 44 days after operation. At postmortem examination, the transplanted fascia was firmly healed in place. Microscopically it was found normal in structure and staining characteristics.

Rittershaus. Operation for fæcal fistula, situated in a patch of granulation tissue and complicated by a very large ventral hernia. The fistula was excised, but the infected layers of the abdominal wall could not be approximated. A large sheet of fascia lata was implanted in the defect, its inner surface being in contact with the suture line in the intestine. There was slight discharge from the wound for a few days. It healed firmly, however, and the patient was well, free from infiltration in the scar and from postoperative hernia when seen one and one-half years later.

Riese. Operation for purulent sinus and hernia after appendectomy. There were many adhesions; part of the cæcum had to be resected. The whole field was infected. The peritoneum was sutured under tension. A sheet of fascia lata 10 x 15 centimeters was implanted to replace the defect in the abdominal wall that could not be closed. A small section from the edge of the transplant became necrotic and escaped from the wound; the remainder healed in place. The final result was excellent; a hernia did not develop.

Schmid. Fascia transplanted into a defect at operation for ventral hernia. An abscess developed in the wound, sloughing of subcutaneous tissues and discharge of sutures followed, but necrosis of the transplant did not ensue. The wound healed firmly.

Joffe. Intestinal fistula and hernia following appendicitis. At operation the fistula was closed but the layers of the abdominal wall could not be approximated. A sheet of fascia 4 x 5 centimeters was taken from the anterior rectus sheath and implanted into the defect. Partial necrosis of the transplant followed. Nevertheless, the wound healed solidly and a hernia did not appear.

An analysis of all these experimental and clinical observations leads to the conclusion that the success of fascia transplants over suture lines or in small defects of the hollow viscera, or into a frankly infected field, can always be considered problematical, and in the nature of a fortunate accident. It is, therefore, not surprising to find that writers consider fascia transplantation neither desirable nor indicated under such circumstances. The results I shall have to report are at absolute variance with those hitherto encountered. They urge, I believe, a complete revision of the subject. Despite these experimental results, however, the practical aspect of fascia transplantation into defects of hollow viscera (as well as into ordinary infected fields), remains largely a question of the future. At the present time the following viewpoint, I believe, is justifiable:

It is realized that necrosis of fascia transferred to the fields in question may result in a deep-seated phlegmon or a complicated fistula. Furthermore, a serious complication — perhaps a fatal one — might follow if there occurred sloughing of, or perforation through, a transplant bridging a defect of one of the hollow viscera. *A priori*, therefore, no matter how satisfactory the experiments to be detailed, their application to the human being can be considered only when the usual surgical measures offer no promise of relief. Unfortunately, this state of affairs exists in some of the difficult problems that are encountered, problems too well known to be discussed here. It was in part as a suggestion for their solution that the studies in transplanting fascia into defects of hollow viscera were undertaken.

Technique of Fascia Transplantation into Visceral Defects with Special Reference to the Hollow Organs

No important new principle was employed in the methods of fascia transplantation that I practiced. Defects were made as previous experimenters had made them, the same fasciæ were transplanted, the technique was, in general, the same. The only explanation that can be offered for the satisfactory results obtained in types of experiments found unsuccessful in the hands of others, is to be found in the *details* of the technique employed.

The one significant difference was in the method of fixing the transplant at the defect. All previous experimenters sutured sheets of fascia *over* defects, to the walls of the viscera beyond the cut margins. By this method they believed that the transplant would be best nourished from the cut edge of the organ, and that it would offer the greatest resistance to tension and the least chances for leakage. In my early experiments this method was followed. It was found that leakage readily occurred between the surface of the organ and the adjoining surface of the transplant, and that the resistance to tension was not great. Evidently a method was required that would prevent the cut margin of the organ from rolling back, would give sutures a firmer hold by being passed through *all* the layers of the organ, would invite the overgrowth of the lining mucous membrane of the hollow viscus, and would most readily supply provisional nutrition to the transplant. These requirements were met by suturing fascial sheets *into* visceral defects. The results of the application of this method were remarkably satisfactory, as will be seen in the various groups of experiments to be recorded.

The only additional differences in technique were in the method of suturing and of hæmostasis. Concerning the latter, previous experimenters took pains to clamp and ligate bleeding vessels at the margin of the defect made in the organ. Considerable devitalization was thus unavoidable, exactly where good nutrition was most desirable. By implanting fascia into the defect, bleeding vessels could be readily caught in the fixating sutures, and ligatures were not necessary. It was also to diminish devitalization that these sutures were not placed as close together as others had advised. Evidently as a result of the method of hæmostasis and application of sutures, and, above all, of the method of implanting fascia *into* and not *over* the defect, *the successful outcome of many of the experiments could be anticipated with absolute certainty.*

Some details of technique will now be considered. Good operating-room asepsis is essential, and that it existed is demonstrated by the almost complete absence of wound infections throughout the various experimental groups. Dogs were the only animals used. The day before operation they were bathed and the skin epilated with barium sulphide paste well beyond the fields of the planned incisions. Ether anæsthesia was employed in all cases. After complete anæsthetization, the skin was thoroughly cleansed with soap and water, alcohol, and 1:1000 bichloride solution.

The organ to be operated upon is exposed, drawn out of the wound (when feasible), and isolated by moist packings. Four points in the wall of the organ are marked by silk threads, and the line of excision passes immediately beyond them. The distance between these points is not estimated but is measured (with a sterilized steel tape). Leakage is prevented, in operations on the

stomach and intestine, by suitable clamps; the contents beyond the clamps are sponged away as soon as the viscera are opened. After the desired excision of the walls of these organs has been made, the cut margins usually evert promptly and the defect diminishes in size. This should not influence one to replace it by a smaller sheet of fascia, for pronounced narrowing of the lumen of the intestine, diminished capacity of the bladder, etc., will naturally result. In fact, it should be determined both by measurement and by guide sutures, that the fascia removed for transplantation is slightly larger than the defect made in the organ.

Fascia from the abdominal wall is fairly satisfactory, is conveniently obtained at abdominal operations, and has been used in a small number of the experiments. Compared with fascia lata, however, it has a number of disadvantages, which apply as well to the human being. It is not as strong, as easily obtained, as smooth, or as large in uninterrupted extent; hernial protrusions followed in two instances when large sections were removed. Therefore fascia lata was employed invariably in all the later experiments. The section of fascia removed should conform closely in shape with the defect made in the organ. Great care is to be observed in its removal. The transplant should receive minimal handling. The lines of incision in the fascia lata should be clean-cut. Portions of the deep surface should not be left behind. The transplant is, of course, quite useless if it has been perforated. The lowest and most dorsal part of the fascia lata is strongest and is, therefore, preferable in most instances.[1] After its shining superficial surface is laid bare, two longitudinal incisions, the desired distance apart, are made down to the underlying muscle. The bridge of fascia between them is elevated by gentle blunt dissection. Its removal is completed by joining the ends of the two incisions, either straight across or with a curve corresponding to the margin of the visceral defect to be replaced. Although the superficial as well as the deep surface of the fascia has been successfully used to face the lumen of hollow organs, it is preferable to turn inward the smoother (deep) surface of fascia lata. The fascia may be placed in warm saline solution before transferring it. This makes it somewhat succulent, however, and not so easily handled. The best procedure is, first to prepare the defect and then to implant the fascia directly into it.

Fine silk sutures were employed in all the experiments and were used on very thin half-curved needles, to avoid making large rents in the fascia. Black silk was used in many instances in order to outline clearly the situation of the transplant. The sheet of fascia is fixed into the defect at 4 points by sutures passed through it from within outward, after having been passed through all the layers of the cut edge of the organ. These sutures are left long. Two on one side are drawn upon and a continuous suture made between them. This suture is passed from without inward through the fascia, and in the opposite direction through all the layers at the cut edge of the organ. This method of passing the sutures is not essential, however, for satisfactory results have been obtained with other methods, provided all the layers of the organ and the fascia, as well, were securely grasped. With any method of suturing, the stitches are placed two or three millimeters apart, not so close as to devitalize the tissues, nor so far apart as to permit gaping. The bite taken through the fascia should be slightly larger than that through the viscus, and, as each stitch is pulled taut, the edge of the fascia is gently drawn upon on both sides of the suture to make it overlap slightly. Every third or fourth stitch is tied. The beginning and the end of the continuous sutures are tied to the fixation sutures. The second, third, and fourth continuous sutures complete the ring and make an uninterrupted suture line of very slightly overlapping fascia. It is important that the transplant should fit in place without fold or wrinkle. If the cut edge of the organ gapes between sutures, additional ones are required from the margin of the fascia to points on the surface of the organ some distance from the primary suture line. Very few will be necessary if the size and shape of the transplant

[1] Similarly, in the human being the area of fascia lata above the external surface of the knee-joint (the iliotibial band) is preferable especially when great strength is required.

Fig. 1. Diagrams showing the previously employed method of fixing the transplanted fascia over the defect (on the right); and the method of suturing the transplant into the defect, as practiced in the experiments and cases to be described.

are correct and the primary tier of sutures is accurately placed. A complete secondary tier was used in only a very few experiments.

A fluid diet for several days is given after operations on the alimentary tract. This diet is continued for a week or more after operations on the œsophagus. It is then followed by semi-solid nourishment. Neither a permanent catheter nor the administration of drugs was found necessary after operations on the bladder or ureter.

I. FASCIA TRANSPLANTS INTO DEFECTS OF THE BLADDER

These experiments are described first, and will be taken up in greater detail than any of the subsequent ones, because the results obtained have been so striking. The largest number of experiments were performed in this group, yet the outcome of every operation was successful, even when as much as one-half, approximately, of the bladder-wall was replaced by fascia. Apart from the absence of contractility of the filled defect, the functional results were perfect; in fact, resistance to hydrostatic pressure was found to be greatest at and about the newly formed bladder-wall. It is of interest to note that vesical calculi never developed when fascia was employed to replace the defect, but were present around fat transplants used for this purpose. A remarkable feature of these experiments was the development of macroscopic plaques of true bone at the site of transplantation. This began astonishingly soon after operation and reached its height in about two months. Relatively little significance would have been placed upon the formation of osseous tissue were it not for the fact that it developed invariably in all the experiments. Not only bone, but also cartilage and bone-marrow appeared, as well as an ensheathing tissue akin to periosteum. These observations will be detailed. It may be stated here that, from the practical side, the development of bone did not in any way interfere with the functional result. On the contrary, this was probably enhanced by the increased strength of the newly formed bladder-wall. The latter term is used advisedly, for, as will be seen, the results do not depend upon healing by shrinkage of the defect but upon the replacement of the defect by new tissue. Another feature of considerable interest was the extension of smooth muscle-fibers from the margin of the bladder-wall across the site of the defect.

Before detailing the experiments, the previous work done in this field should be reviewed. It has already been said that the statements one finds in the literature are erroneous in referring to appreciable vesical defects having been replaced successfully by fascia transplants. They are based on studies by Hohmeier, and by Kostenko and Rubaschew. Upon analysis of Hohmeier's experimental work, it is found that the results were quite unsatisfactory. Four experiments were performed upon fascia implantation into bladder defects. In one, a "peritonitis from unknown cause," resulted in death a few days after operation. Perforations through the transplants occurred six and nine weeks after operation, in two succeeding experiments. It was only in the fourth that "the fascia appeared firmly healed in place." In this instance death resulted from "distemper" three weeks after operation; the period of observation is evidently not sufficiently long to suggest any definite conclusion, especially in view of the other experiences. Kostenko and Rubaschew[1] found that fascia transplants *occasionally* prevented leakage from

[1] The original publication is unfortunately inaccessible. Abstracts in the *Zentralblatt fuer Chirurgie* and in papers by Kornew and others are the basis for my remarks.

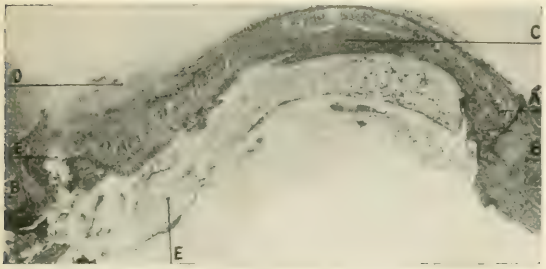

Fig. 2. Pathology No. 3368. Two days after fascia transplant into defect of bladder. *A*, The two layers of fascia attached firmly to bladder-wall at *B*, *B*; *C*, layer of fibrin; *D*, leucocytes on free surface; *E*, adherent omentum.

the bladder when implanted into very small defects (defects less than 2 x 2 centimeters, how much less is not stated). The periods of time after operation at which the observations were made are not given. Healing in these occasional instances depended upon shrinkage of the defect and approximation of the cut edges of the bladder-wall. In general these experimenters agreed with Joffe, who demonstrated that fascia often prevented leakage when implanted over vesical defects after the mucous membrane had been sutured, but that necrosis of the transplant and perforation followed uniformly when the lips of mucous membrane were not approximated.

On the other hand, the experiments of Koenig, Hohmeier, and the others abovementioned, demonstrated that fascia affords a strong barrier against leakage when transplanted over suture lines in the bladder.

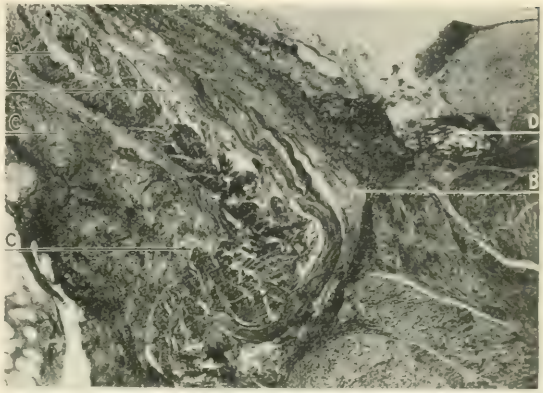

Fig. 3. Pathology No. 3368. Enlargement at *A* in Fig. 2, showing details of repair. *A*, The two layers of fascia undergoing degeneration; *B*, thick layer of fibrin sealing the chink between transplant and bladder-wall; *C*, layer of fibrin, to which the omentum is adherent; *D*, silk suture.

The procedure has been successfully employed in the human being by Koenig and by Kostenko and Rubaschew.

Eighteen experiments were made upon fascia transplantations into vesical defects. There were four fatalities; only one, in which approximately five-eighths of the bladder was replaced by fascia, being due to necrosis of the transplant and perforation. The other three followed infection or rupture of the abdominal wound. The defects made in the bladder varied in size, from 2 x 2 centimeters to about one-half of the bladder-wall.[1] The

[1] In the description of experiments the measured size of the defects will be given rather than their relation to the size of the bladder. The latter varies too greatly with the amount of contained urine to be accurate.

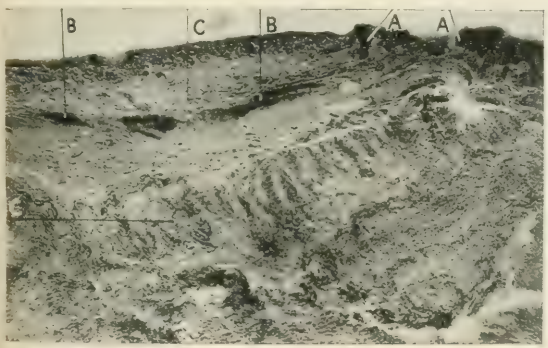

Fig. 4. Pathology No. 3367. Six days after fascia transplant into vesical defect. *A*, Deposits of lime salts on the surface and *B*, *B* in the depths; *C*, *C*, fascia undergoing hyaline degeneration.

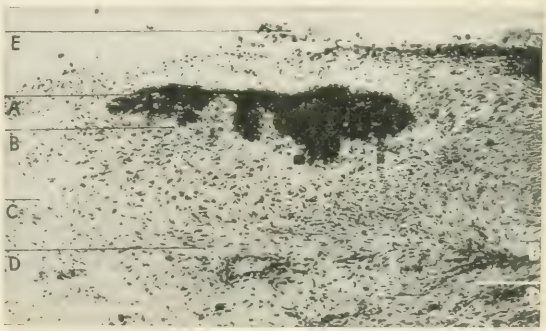

Fig. 5. Pathology No. 3403. Seventeen days after fascia transplant into defect of bladder. *A*, Bone; *B*, osteoid tissue; *C*, loosely woven connective tissue occupying defect; *D*, *D*, *D*, strands of smooth muscle in defect; *E*, *E*, fragments of epithelium on surface.

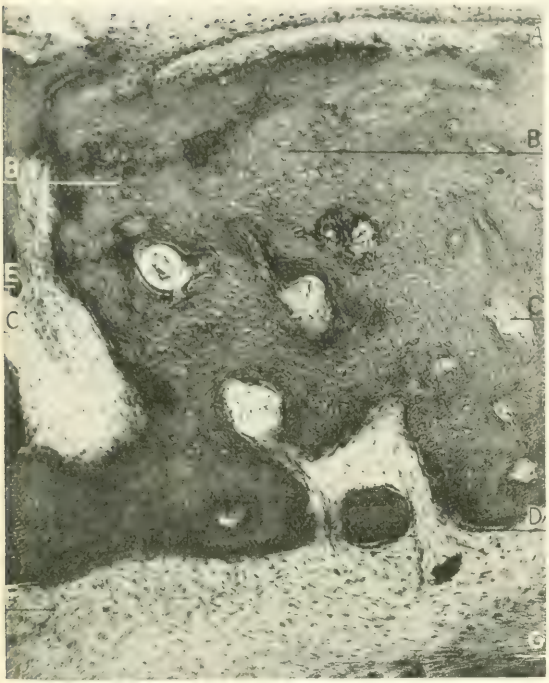

Fig. 6. Pathology No. 3518. Seven and one-half weeks after fascia transplant into defect of bladder, showing details of the tissues occupying the defect. *A*, layer of epithelium; *B*, *B*, clusters of cartilage-cells in the bone; *C*, *C*, bone-marrow; *D*, row of osteoblasts; *E*, osteoclast; *F*, osteoid tissue; *G*, smooth muscle.

Fig. 7. Pathology No. 3518. Seven and one-half weeks after fascia transplant into defect of bladder, showing details of cartilage in relation to bone.

specimens were examined from two days to five months after operation. The following are a considerable proportion of the experiments, chronologically arranged, and chosen to illustrate various findings.

Experiment Dog 220. Small male. Opera-

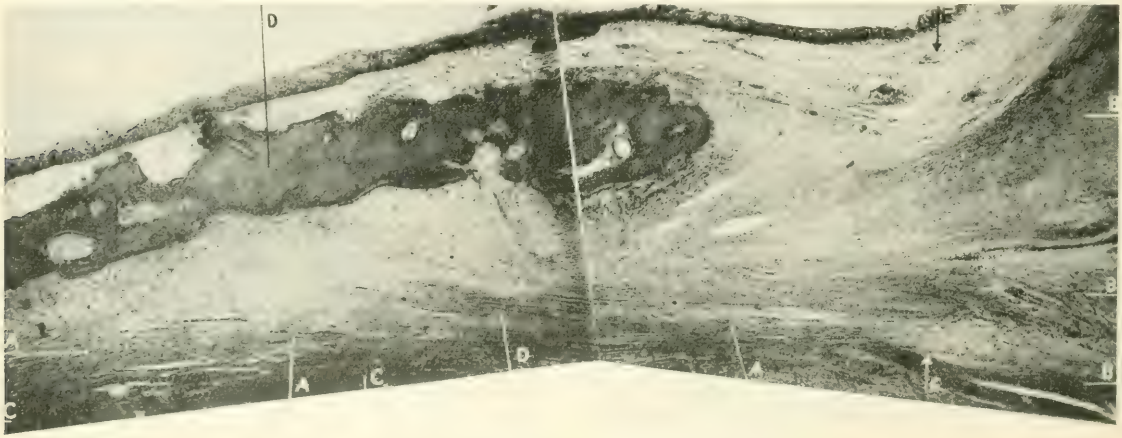

Fig. 8. Pathology No. 3518. Seven and one-half weeks after fascia transplant into defect of bladder, showing general configuration of tissues occupying defect and overgrowth of smooth muscle. Arrows indicate the approximate line of transition from bladder to defect. *A*, *A*, *A*, *A*, Smooth muscle of defect continuous with *B*, *B*, *B*, that of bladder-wall; *C*, *C*, abscess; *D*, cartilage.

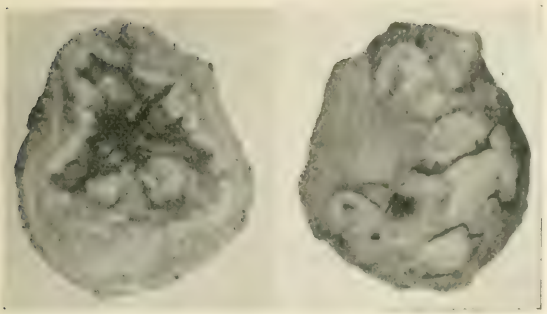

Fig. 9. Pathology No. 3843. Ten weeks after fascia replacement of large quadrilateral defect of bladder. To the right is the moderately distended unopened bladder, the adherent omentum outlining the size and shape of the defect. To the left is the half of the bladder which has been operated on, showing the type of mucous membrane overgrowth.

tion, March 9, 1915. Right hypogastric incision. Bladder moderately full. Isolated from abdominal cavity by moist packings. A circular section from its vertex, 2½ x 2 centimeters removed. Considerable oozing from cut wall, no ligatures applied. Sheet of fascia lata from upper thinner area, of appropriate size and shape, removed and sutured into defect with black silk. When suture was complete the defect, as bridged by fascia, measured 2½ x 1¾ centimeters. Reinforcing sutures not used, the primary tier making snug approximation. Layer suture of the abdominal incision.

Postoperative course. Temperature 102° the day after operation. Wide separation of the wound. Death March 11, two days after operation.

Postmortem examination. Very extensive cellulitis, numerous pockets of pus in all the layers of the abdominal wound. No peritonitis. Anterior surface of bladder with a small part of the transplant adherent to parietal peritoneum in the immediate vicinity of the abdominal-wall infection. The peritoneum is here deeply congested, discolored, shaggy; evidently the infection would soon have invaded the peritoneal cavity.

Congested tongue of omentum firmly adherent at site of fascia transplant. Bladder distended with cloudy urine (containing many pus and red cells); no sign of leakage. Bladder removed and subjected to great hydrostatic pressure; absolutely no leakage. External surface of the transplant not seen (omentum adherent). Viewed from within, the silk sutures outlining transplant showed that defect had not shrunk. Submucous hæmorrhages in bladder-wall near cut margin. Many fine shreds hang from transplant; no concretions about them.

Microscopic examination. Surgical Pathology No. 3368. The fascia transplant is in part broken up and undergoing hyaline degeneration. In some places only a few remnants are seen. The surface facing the lumen (to be termed the "free" surface in all further descriptions) is occupied by numerous

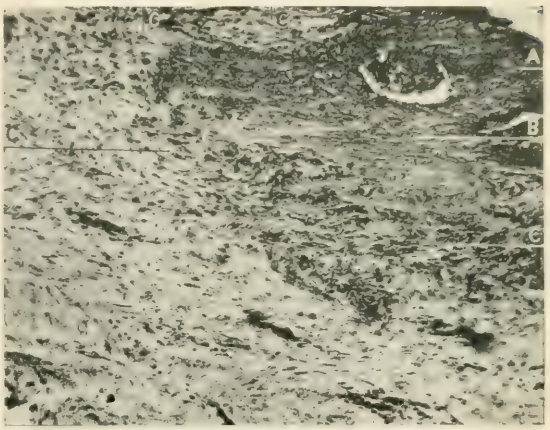

Fig. 10. Pathology No. 3843. Ten weeks after fascia transplant into vesical defect. Showing shading of bone, *A*, into osteoid tissue, *B*, and of this into an adjoining periosteum-like layer of tissue, *C*, *C*, *C*, *C*.

leucocytes, some of which are found among the fascia bundles. The opposite surface of the transplant is covered by a thick layer of fibrin, to which the omentum, rich in blood-vessels, is adherent. Silk sutures at the surface mark the line of demarcation between bladder-wall and transplant. All the layers of the bladder-wall stop sharply at the edge of the defect. They are united to the transplant by a very thick layer of fibrin. There are very many blood-vessels (filled with red blood-cells) near the cut margin of the bladder wall.

Experiment Dog 210. Large male. Opera-

Fig. 11. Pathology No. 3842. Two and one-half months after fascia transplant into defect of bladder. Showing bone extending to the extreme margin of the defect, and very active changes in the osseous tissue. *A*, Site of transition from bladder-wall to tissues of the defect; *B*, large vascular marrow-space in which osteoblasts and osteoclasts are seen.

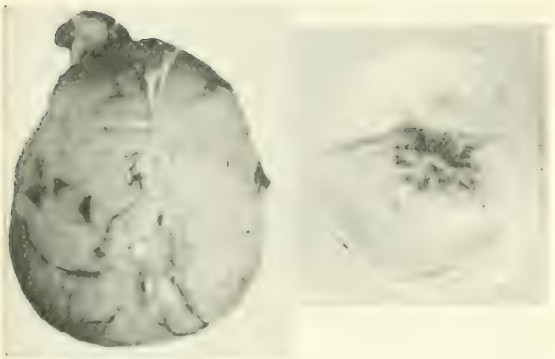

Fig. 12. Pathology No. 3827. Two and one-half months after fascia transplant into a vesical defect. To the left is the unopened bladder, maximally distended to show the resistance of the tissues filling the defect, situated within the dotted lines. To the right is the interior view, showing the bone plaque in the center.

tion, March 5, 1915. Right hypogastric incision. Bladder extremely distended, oval section removed from anterior aspect measured 3 x 2½ centimeters. Very little bleeding. Lower portion of fascia lata chosen, section of appropriate shape, 2½ x 3¼ centimeters removed, implanted into defect with black silk sutures. Three additional reinforcing stitches. Actual defect then measured 3 x 2 centimeters. Some difficulty in suture of abdominal incision.

Postoperative course. High temperature, infiltration of the wound, no evidence of peritonitis. Death on March 11, six days after operation.

Postmortem examination. Whole lower abdominal wall intensely infiltrated; all the layers widely infected about the line of incision, the musculature in particular being necrotic and liquefied. No peritonitis. Deeply congested slip of omentum ad-

Fig. 13. Pathology No. 3827. Two and one-half months after fascia transplant into vesical defect, showing an unusually large marrow-space close to the epithelium.

herent to parietal peritoneum at the incision and to the site of operation on the bladder.

Bladder tensely distended with clear urine. No evidence of leakage. Both external and internal surfaces of bladder much congested, more so toward the edge of the defect. Here there are several small submucous hæmorrhages. A rather shreddy thin layer of tissue appears to overlay the inner surface of the transplant; exact relation not determined in order to preserve it for microscopic examination.

Microscopic examination. Surgical Pathology No. 3367. The transplant has undergone considerable hyaline degeneration, being scarcely recognizable in several places. Its free surface is covered by a homogenous layer staining faintly blue. Here there are lime deposits, which extend into the depths of the transplant at one place. A layer of young

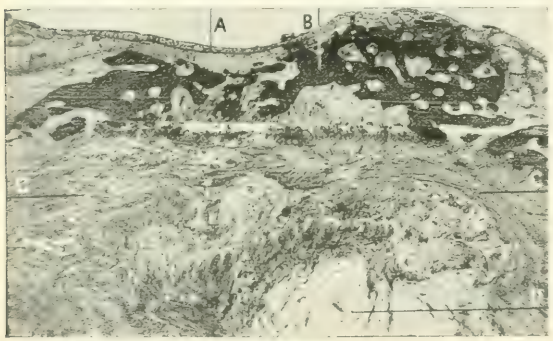

Fig. 14. Pathology No. 2895. Three months after fascia transplant into a defect of the bladder. showing how the plaque of bone reinforced a thin part of the new bladder-wall. *A*, Continuous layer of epithelium, in heaps at the extreme left; *B*, bone; *C*, connective tissue and smooth muscle; *D*, omentum.

Fig. 15. Pathology No. 2895. Three months after fascia transplant into a defect of the bladder, showing the thick vascular layer of connective tissue beyond the bone plaque.

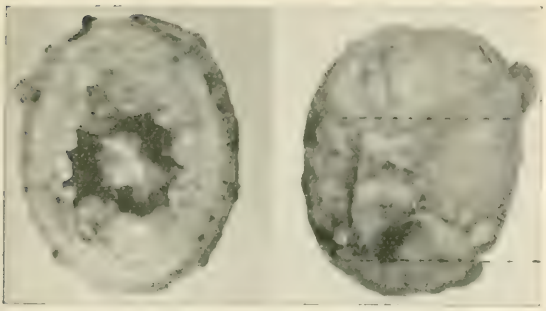

Fig. 16. Pathology No. 3844. Three months after fascia transplant into a bladder defect. To the right is the unopened, empty bladder, the site of the defect being between the dotted lines. To the left is the interior view, showing the bone plaque at the center.

connective tissue, containing many round cells, occupies the deep surface of the transplant; to this the highly vascular omentum is adherent. The ends of the strip of fascia merge almost insensibly into the adjoining bladder-wall; only the silk sutures definitely mark the boundary.

Experiment Dog 247. Medium sized, male. Operation, March 19, 1915. Curved hypogastric incision. Bladder almost empty. Defect of antero-superior wall 3 x 2 centimeters. Moderate bleeding from cut edge. Thicker part of fascia lata, 3½ x 2½ centimeters sutured into defect with black silk; a few reinforcing sutures required. Actual defect bridged then measured 3 x 2 centimeters. Layer suture of wound.

Postoperative course. Wound separated soon after operation, some purulent discharge at first, then showed tendency to heal but never closed. Death from large hæmorrhage from wound on April 5, seventeen days after operation.

Postmortem examination. Tissues very pale. Source of hæmorrhage probably the epigastric vessels. Bladder greatly distended with urine, no bulging at site of transplant. Latter outlined by black silk sutures unless they have migrated; no shrinkage, as determined by measurement. Thin layer of bluish omentum adherent to part of transplant. Part of fascia visible is smooth and glistening. Bladder adjoining transplant faintly purple in color. Internal appearance of transplanted area is that of a clean smooth flat healing ulcer. Few old submucous hæmorrhages near edge of defect. Newly formed tissue about transplant is of same thickness as bladder-wall.

Microscopic examination. Surgical Pathology No. 3403. The fascia transplant is not recognizable as such. A loosely woven fluid-like connective tissue occupies its site. In this tissue near (in some sections directly at) the free surface are small masses of bone. The latter is laid down about cells in the typical trabeculated framework, shading off into osteoid tissue by insensible gradations. In some of the slides only deposits of lime are present

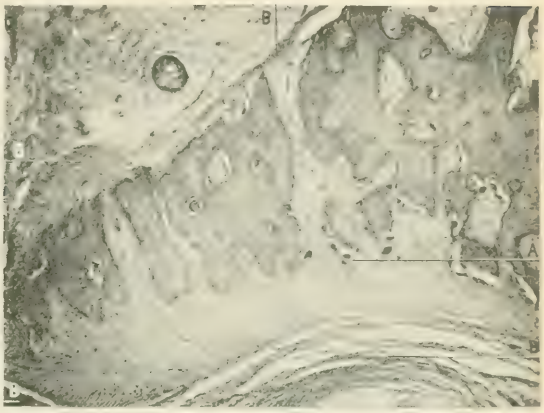

Fig. 17. Pathology No. 3844. Three months after fascia transplant into bladder defect. *A*, Preponderance of osteoclasts; *B*, *B*, *B*, *B*, layer of ensheathing periosteum-like connective tissue.

in situations identical with the bone deposits. The fusion between the bladder-wall and the tissue filling the defect is complete. Beneath the above-described loosely woven layer of tissue, smooth muscle-bundles are seen here and there. They are found to be continuous with the muscle-wall of the bladder at the edge of the defect. The omentum is intimately attached to a layer of connective tissue beyond the muscle-bundles in the defect. Fragments of bladder epithelium are seen here and there on the free surface of the transplant. Presumably they represent epithelial overgrowth from the margin of the defect; however, a continuous layer of epithelium was not found in any of the sections.

Experiment Dog 242. Rather large male. Operation, March 25, 1914. Incision in right hypogastrium. Bladder distended. Points marked at such distances that removal immediately beyond them would be an excision of about half the bladder-wall. Defect measured 4 x 5 centimeters, extending close to the insertion of the left ureter. Fascia from abdominal wall, slightly larger than this, sutured into defect with white silk. Gap in abdominal fascia partly sutured. Suture of wound.

Postoperative course. Two weeks after operation tympanitic hernial protrusion of abdominal wall at site of fascia excision. This persisted to the end. No urinary symptoms noted. Development of distemper, for which animal was chloroformed April 27, thirty three days after operation.

Postmortem examination. Typical evidences of distemper in examination of the respiratory system.

Fairly broad adhesions of omentum to empty bladder at site of transplant. Vesical serosa deeply congested in region of operation. Measurement between sutures, faintly seen when interior of bladder was inspected, showed slight contraction. Mucous membrane appeared to have grown over the defect down to an area 1½ x 1½ centimeters. This area was occupied by a firm whitish smooth

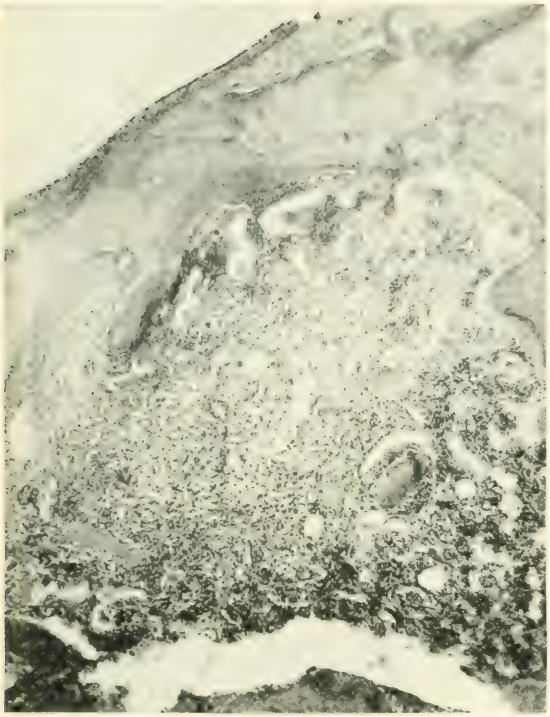

Fig. 18. Pathology No. 3612. Four months after fascia transplant into a defect of the bladder. Showing the large marrow-spaces and the extreme development of bone-marrow.

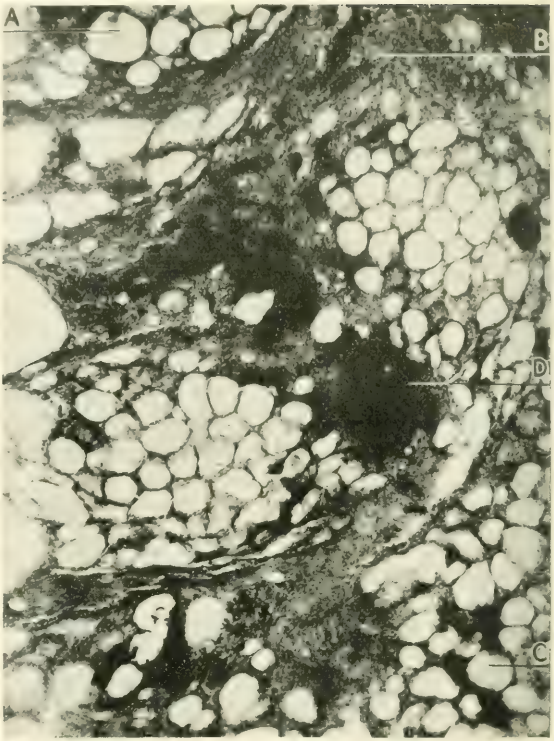

Fig. 19. Pathology No. 3506. Twelve days after transplant of fat into a defect of the bladder. Deposits of lime salts about the fat-cells and in the connective tissue between them, near surface at *A*, *B*, and in depths at *C*, *D*.

plaque, covered by a thin translucent pink membrane (mucosa?). Tested by water distention, no evidence of diminished bladder capacity. Ureters intact.

Microscopic examination. Surgical Pathology No. 2997. A large (macroscopic) plaque of bone occupies the free surface of the defect. It is of irregular shape, especially upon its deeper aspect.

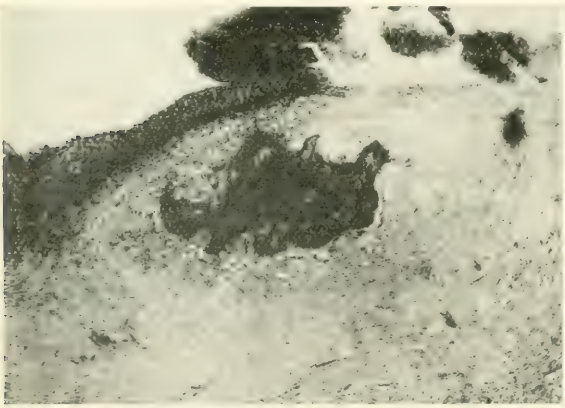

Fig. 20. Pathology No. 3613. Fat transplant into defect of bladder, showing bone formation 2½ months later. Fragmentation of epithelial layer accidental.

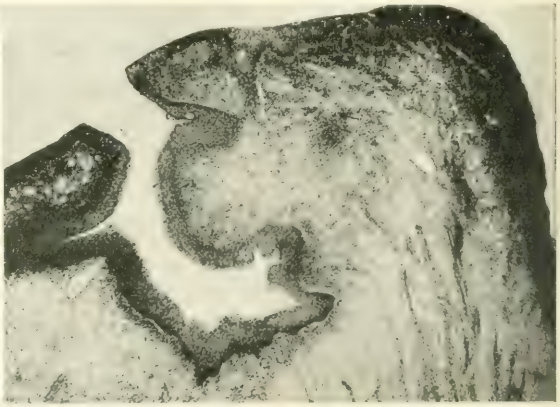

Fig. 21. Pathology No. 3613. Two and one-half months after fat transplant into defect of bladder, showing the villous projections.

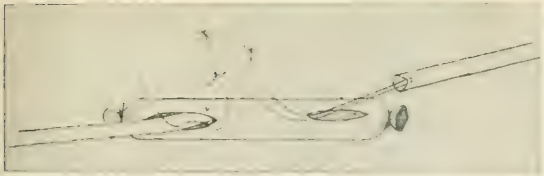

Fig. 22. Diagram illustrating the method of fixing the ends of a resected ureter into a previously made tube of fascia. On the right, the ureter is being drawn through a slit in the tube; on the left, the wall of the ureter is being fixed to the tube at the slit. (The slits are disproportionately large.)

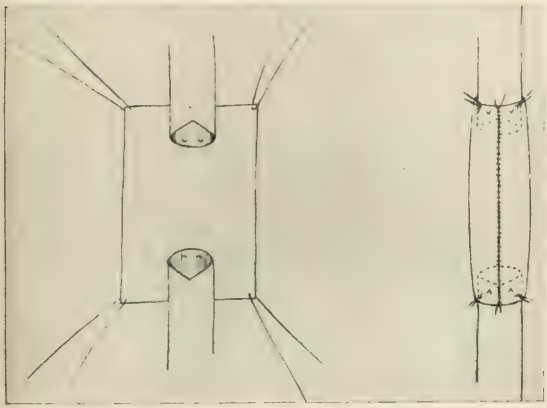

Fig. 23. Diagram to show the method of constructing a fascia tube between the ends of a resected ureter.

The mass of bone is hollowed out into spaces occupied by a loosely woven tissue rich in cells and in blood-vessels, a tissue analogous to young bone-marrow. The free surface of the bone plaque is covered by a layer of epithelium continuous with the bladder epithelium. The deep surface is covered

Fig. 24. Exterior views at sites of œsophageal defects replaced by fascia. The tubes are distended with varying amounts of fluid. On top, sixteen days after operation; in the middle, twenty-three days after operation; at bottom, one month after operation.

by a thin layer of dense connective tissue analogous to periosteum. Beyond this is a broad zone of dense, poorly staining connective tissue (scar tissue) in which are seen muscle-bundles continuous with those of the bladder-wall at the defect. The tissue occupying the defect merges insensibly with the bladder-wall. Silk sutures identify the approximate position of the defect; it is evident that little, if any, shrinkage has taken place.

Experiment Dog 285. Large female. Operation, April 9, 1915. Transverse hypogastric incision through fascia, muscles, and peritoneum, split

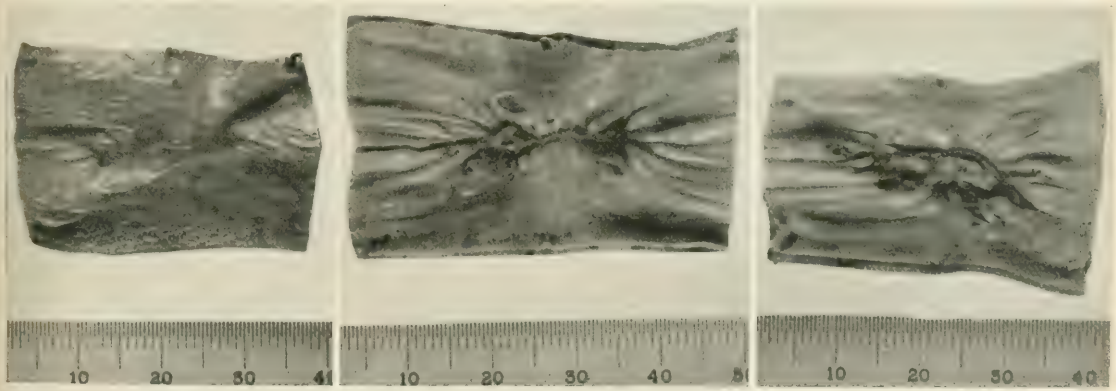

Fig. 25. Appearance of interior at sites of œsophageal defects replaced by fascia. *A* (at left), One month after operation; B, twenty-three days after operation; C, sixteen days after operation.

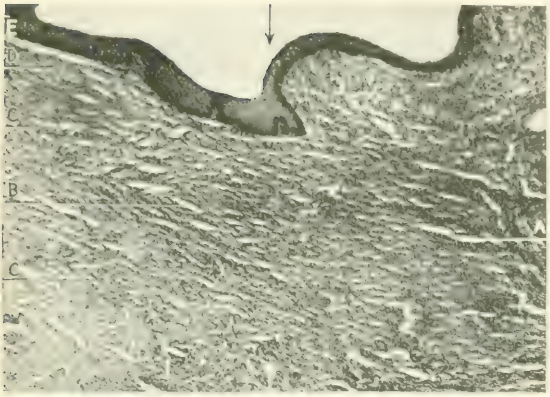

Fig. 26. Pathology No. 3884. Sixteen days after fascia transplant into defect of œsophagus. Arrows indicate line of transition from œsophageal tissues (to the right) to those of the defect (to the left). *A*, Muscle layer of œsophagus extending into defect at *B*; *C*, *C*, degenerating fascia; *D*, organized granulation tissue on the surface of the transplant; *E*, regenerated epithelium raised in folds.

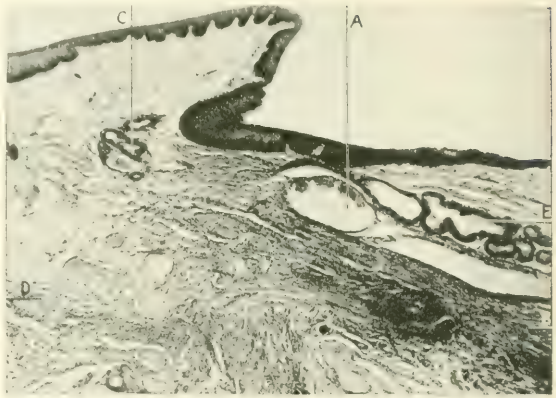

Fig. 27. Pathology No. 3883. Twenty-three days after fascia transplant into œsophageal defect. *A*, Silk suture defining line of transition from œsophageal wall to tissues of defect; *B*, muscle layer of œsophagus extending into defect; *C*, mucous glands found in defect identical with *E*, those of œsophagus; *D*, degenerating fascia.

longitudinally. Bladder moderately distended. Points marked so that excised wall would measure 4½ x 4 centimeters. Fascia lata slightly larger than this sutured into defect with black silk. Beside the primary tier of sutures three additional stitches were placed at points where mucosa pouted slightly between sutures. Small hæmatoma in wall of bladder not touched.

Postoperative course. Uneventful. Slight mange. Animal chloroformed June 2, seven and a half weeks after operation.

Postmortem examination. Bladder fairly full. Ureters intact. Moderate omental adhesion at field of operation. Before opening bladder measurement was made of the solid tissue occupying region of transplant, pale and different from the remainder of the bladder. It was 4½ x 3½ centimeters, indicating little if any shrinkage. This was corroborated by inspection of the interior, when the black silk threads approximately outlined the original size of the defect. A layer of translucent, pinkish, jelly-like tissue, carrying numbers of very fine blood-vessels, is spread over the position of the transplant. Visible through it is a pinkish gray very solid plaque of tissue; touched at one point with a needle, it was found bone-like in consistency, new bladder-wall as thick as the normal.

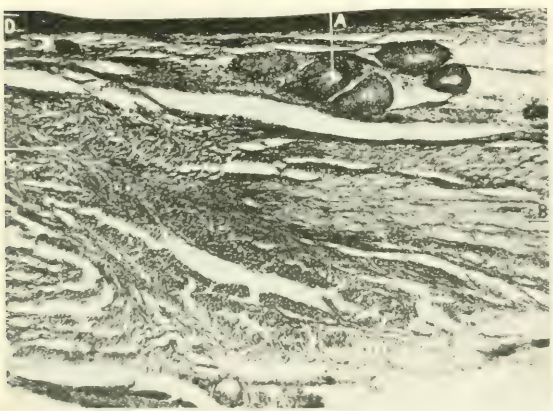

Fig. 28. Pathology No. 3882. One month after fascia transplant into œsophageal defect. *A*, Glands indicating transition line; *B*, musculature of œsophagus extending into the defect at *C*, where it is lost in dense connective tissue; *D*, continuous layer of epithelium.

Microscopic examination. Surgical Pathology No. 3518. A large remarkably well-formed mass of bone occupies most of the free surface of the defect; many typical osteoblasts as well as a number of osteoclasts are seen. Marrow spaces are infrequent and generally small. One end of the bone plaque is fairly smooth and rounded. The opposite end presents two irregular wide-spreading prongs. Filling the space between them and in intimate fusion is a large mass of cartilage (visible macroscopically as a small blue speck). On one side the cartilage-cells are intermingled with the bone-cells; at the other extreme the broad zone of typical cartilage merges gradually into a wide layer of connective tissue akin to perichondrium. In addition to this large deposit of cartilage, there are several small islands of cartilage-cells, scattered throughout the bone plaque. The free surface of the bone plaque is covered completely by epithelium continuous with the normal bladder epithelium. Adjacent to its deep surface is a well-formed layer of connective tissue identical in appearance with periosteum. Beyond this is a thin continuous layer of typical smooth muscle; typical in the color of the stain, in the construction of the cells, in the elon-

gated narrow nuclei. Its continuity with the smooth muscle layer of the bladder-wall can be easily distinguished. Outside the muscle layer there is an abscess, the wall of which brings out the contrast with the smooth muscle. The omentum was adherent to its external surface.

Experiment Dog 41. Male of average size. Operation, December 1, 1915. Transverse incision. Bladder enormously distended. After puncture a quadrilateral strip from vertex, anterior and posterior walls, 5 x 2¼ centimeters, was removed. Six fixation sutures for the fascia transplant were necessary instead of the usual four (see section on Technique). At two points reinforcing stitches were required over the primary tier. Layer suture of abdominal incision.

Postoperative course. Uneventful. Animal sacrificed with chloroform February 8, ten weeks after operation.

Postmortem examination. Broad omental adhesion at site of operation. Bladder-wall under omentum seen to be more opaque, less pink than the rest of bladder, yet smooth and shining. No bulging here with water distention. Inspected from within, mucous membrane apparently covers tissue filling defect except in one small area into which a few black sutures protrude. At this point the bladder-wall appears thinner. Mucosa at defect more corrugated, thicker(?), pinker than over remainder of bladder. Firm shotty nodules felt underneath.

Microscopic examination. Surgical Pathology No. 3843. The free surface of the tissue filling the defect consists of small papillæ or rugæ covered with an unusually thick layer of epithelium continuous with the bladder epithelium. The stroma of these papillæ is rich in blood-vessels and small round cells. A thick layer of dense connective tissue occupies most of the remainder of the defect. Between it and the villus-like layer is a small area of bone. This shades off gradually into osteoid tissue which in turn merges with a layer of periosteum-like connective tissue. An irregularly distributed layer of smooth muscle bridges the defect, lying for the most part in the deeper surface of the cicatricial tissue.

Experiment Dog 35. Operation, November 24, 1915. Transverse incision. Quadrilateral defect 4 x 3 centimeters in the anterosuperior part of bladder replaced by fascial sheet 4½ x 3½ centimeters. In this experiment the vessels in the bladder-wall were unusually large and three were ligated a short distance from the edge of the defect. Four reinforcing stitches at necessary points over the primary continuous suture.

Postoperative course. Nothing unusual. Animal chloroformed February 8, 1916, two and a half months after operation.

Postmortem examination. Omentum adherent to bladder over a very firm plaque of tissue occupying site of defect. This tissue approximates closely the size of the original defect, is differentiated from the remainder of bladder-wall by its less pink color, and its border is well outlined by the black silk sutures. Inspection of the interior discloses mucous membrane covering the region of the transplant except at one place where a silk suture hangs free.

Microscopic examination. Surgical Pathology No. 3842. The fairly large plaque of bone that formed near the surface of the defect shows great activity. Many osteoblasts and osteoclasts are seen, the bone mass being laid down in very irregular grotesque forms. Epithelium is continuous over the site of the defect, even where the bone is prolonged into pointed projections. The connective-tissue layer ensheathing the deep surface of the bone plaque is closely analogous to periosteum. The layer of smooth muscle bridging the site of the defect is not as readily distinguishable as in previous specimens, yet can be seen in the dense connective tissue occupying most of the defect beyond the bone.

Experiment Dog 31. Operation, November 17, 1915. Transverse incision. Defect in bladder accidentally made somewhat larger than fascia lata removed to fill it. Fascia measured 3½ x 2¼ centimeters and was sutured in place under considerable tension. Reinforcing sutures were desirable, could not be placed without narrowing the defect; therefore were not employed. Unusual oozing from cut edge of bladder and of abdominal incision noted at operation.

Postoperative course. Uneventful convalescence. Normal course until January 29, when stools became tarry. Fresh active bleeding from the bowel followed, and the dog succumbed on January 31, two and a half months after operation.

Postmortem examination. Tissues very anæmic. Stomach and intestines filled with old and fresh blood. Source of the hæmorrhage was not found. Peritoneal cavity negative. Omentum broadly adherent at site of operation on the bladder. Latter greatly distended. Silk sutures outlined a circular area approximately the size of the original defect. Peritoneal surface of tissue filling defect not visible through omentum. Viewed from interior, a smooth bony plaque about 2 x 2 centimeters is seen occupying the center of the transplanted area, covered by a thin translucent layer of tissue continuous with the mucous membrane.

Microscopic examination. Surgical Pathology No. 3827. The marrow spaces that are present in the plaque of bone which had formed are easily seen with the naked eye. Microscopically very large blood-vessels as well as numerous small ones are found in the loose-meshed tissue of these spaces. The elongated mass of bone occupies most of the free surface of the original defect, is covered by a continuous layer of epithelium and ensheathed by a connective-tissue layer remarkably like periosteum. This is the only specimen which showed a second independent deposit of bone, in the depths of the cicatricial tissue occupying the defect. Smooth muscle spreads in a thin layer across the defect as in the previous experiments.

Experiment Dog 115. Large male. Opera-

tion, December 10, 1913. Incision in right hypogastrium. Epigastric vessels ligated. Defect in bladder 2½ x 2½ centimeters, replaced by fascia from abdominal wall measuring 3 x 3 centimeters. Several reinforcing sutures. Layer suture of abdominal incision.

Postoperative course. Temperature 101° to 102° for two days, normal thereafter. Some blood in urine the day after operation. Animal chloroformed March 6, 1914, three months after operation.

Postmortem examination. Bladder moderately full. Thin strand of omentum firmly attached at site of operation. The latter is the seat of a rather anæmic, firm, smooth plaque of tissue. Examined from the interior the plaque is bone-like in a small area, very hard, apparently not bony in the remainder. Mucous membrane appears to cover this, as noted in previous experiments. No reduction of bladder capacity. Kidneys and ureters negative.

Microscopic examination. Surgical Pathology No. 2895. A very large area of bone smooth at the periphery occupies most of the free surface of the defect. Epithelial overgrowth is peculiar in the heaped-up islands seen here and there. Otherwise the findings are similar to those already noted.

Experiment Dog 26. Small female. Operation, November 11, 1915. Transverse incision. Circular defect of bladder around vertex, 3½ x 2 centimeters, replaced by a sheet of fascia lata slightly larger.

Postoperative course. Uneventful. Animal chloroformed February 8, 1916, three months after operation.

Postmortem examination. Bladder empty. Thin strand of omentum firmly adherent to it in operative field. The entire vertex of the bladder the seat of a very resistant plaque of tissue, the size of the original defect, outlined by the black silk sutures. Inspected from within the bony character of this tissue is evident. Mucous membrane completely covers the region of the transplant. No shrinkage of bladder capacity.

Microscopic examination. Surgical Pathology No. 3844. The bone plaque is remarkable for its unusual length, almost completely that of the defect (as shown by the position of the silk sutures). Very many osteoblasts and osteoclasts are seen. The ensheathing periosteum-like tissue is unusually well defined. Epithelial and smooth muscle overgrowth as in previous specimens.

Experiment Dog 262. Female, medium size. Operation, March 26, 1914. Bladder empty. Defect 3 x 2 centimeters replaced by fascia lata in the usual way. No reinforcing sutures. Hæmatoma in bladder-wall near cut edge not ligated. Considerable oozing from incised bladder-wall.

Postoperative course. Normal. Animal sacrificed with chloroform July 26, four months after operation.

Postmortem examination. Bladder almost empty. Broad omental adhesion at site of transplantation. The latter not seen clearly through the omentum. The interior of bladder at site of operation revealed a number of silk sutures dangling free, not surrounded by incrustations. The sutures outlined an area almost equaling the original defect in size. A very large plaque of bone the entire length of the original defect and about half its width. Projecting from its base are three broad spurs of bony tissue, fused at their attachment but sharply hooked and covered with minute spines at their tips. Mucous membrane appears to cover the entire bony mass, except, perhaps, at the very tips of the spurs.

Microscopic examination. Surgical Pathology No. 3612. The only unusual feature is the extreme development of the bone-marrow. The marrow spaces are enormous in proportion to the ridges of bone that surround them. They are richly vascular, full of the typical cells of bone-marrow enmeshed in the typical network of areolar tissue. Complete overgrowth of epithelium and of smooth muscle.

The only experiment in which perforation through and leakage from the bladder occurred was as follows:

Experiment Dog 261. Average-sized male. Operation, April 8, 1914. Vertical incision in right hypogastrium. Vessels in bladder-wall going to the outlined defect were very large and were ligated a short distance from the line of excision. Bladder moderately full so that *five-eights of wall* could be fairly well estimated. This was replaced by fascia from the abdominal wall by the usual technique. Layer suture of wound.

Postoperative course. Uneventful until second day then evidences of peritonitis. Death four days after operation.

Postmortem examination. Generalized peritonitis from leakage from bladder through ragged perforation near center of transplant. The part of fascia nearer the suture line appeared well preserved, union at suture line strong. The healthier appearance shaded insensibly to the necrotic at the perforation. Bladder empty. Interior deeply congested.

Fat transplants were sutured into vesical defects in a few experiments, in an attempt to determine (1) if tissues other than fascia could be satisfactorily employed for the purpose, and (2) if bone would develop under such circumstances. Although leakage did not occur, the functional results were unsatisfactory. It was found that extrusion of the fatty tissue into the bladder took place, and that the lips of the defect of the bladder drew together as the transplant was expelled. The results were a diminution in bladder capacity and the formation of vesical calculi, to an enormous extent in one instance. Lime de-

posits, similar in distribution to those seen after fascia transplantation, were found in the bladder wall, at the site of the defect, soon after operation. The early stages of bone formation were also seen, in a specimen examined a somewhat longer time after operation. It is therefore fair to assume that, if the defects had not become obliterated or if the experiments were continued for a sufficiently long time, extensive bone development identical with that after fascia transplantation, would have taken place.

Experiment Dog 340. Young male of good size. Operation, May 7, 1914. Transverse incision. Fat from right side of abdominal wound 3½ x 3½ centimeters. Removed and sutured into a 3½ x 3 centimeters defect in the usual way. The fat could not be as easily handled as fascia, but sutures held very well in it. Several additional stitches required to tack down loose ends of the fatty tissue. Layer suture of wound.

Postoperative course. Uneventful until the development of distemper for which reason animal was chloroformed on May 19, twelve days after operation.

Postmortem examination. Extensive omental adhesion at site of operation on bladder; the underlying tissues not visible. Bladder moderately full, no evidence of leakage. Viewed from interior, a considerable mass of calcareous material is found loosely attached at the field of operation. After its removal the projection of the fatty mass into the lumen is seen. Mucosa apparently has partly grown over the defect.

Microscopic examination. Surgical Pathology No. 3506. A mass of areolar tissue fills the defect. Its free surface is composed of numerous shreds of fat, some slightly, some almost completely detached. Its deeper layers are crowded with polynuclear leucocytes and small round cells. Deposits of lime are seen, not only between fat-cells near the surface, but also in larger masses in the depths. The bladder-wall stops abruptly at the margin of the defect. Here the bladder epithelium dips deep between transplant and bladder-wall, but shows evidence at only one point of attempted extension across the site of the defect. Bladder-wall and transplant fuse intimately. Omentum is attached to the deep surface of the fatty tissue.

Experiment Dog 325. Female of medium size. Operation, April 30, 1915. Transverse hypogastric incision. Fat between mammary glands, with possibly a narrow strip of gland on each side, excised. Its surface measurement was 4 x 4 centimeters, thickness varied from ½ to 1¼ centimeters. Defect in anterosuperior wall of bladder was 4 x 4 centimeters. Fat sutured in place without difficulty. Oozing from cut bladder-wall did not appear to be as well controlled by contact with transplant as in fascia transplantations. Layer suture of abdominal wound.

Postoperative course. Uneventful except for frequent urination noted after the second week. Animal chloroformed July 19, two and a half months after operation.

Postmortem examination. Fine omental adhesion to bladder at site of operation. Underneath it the wall of the bladder deeply congested, no evidence of any new tissue filling defect. Although tense with contained urine, bladder was small, could not be made appreciably larger by water distention; capacity manifestly greatly reduced. Occupying almost the whole interior of the bladder is an enormous, mulberry-shaped calculus. This is found to be built about the disintegrated, extruded fat transplant. After its removal, mucous membrane was found entirely covering site of the defect. Its appearance not normal, deep red, injected and raised into fine papilloma-like projections at several points.

Microscopic examination. Surgical Pathology, No. 3613. The site of the defect cannot be distinguished. There are no traces of the transplant which, as was seen above, had extruded into the bladder. The musculature of the bladder-wall has united at the defect in the form of large bundles irregularly interlaced. The free surface of the bladder-wall at the site of the defect is occupied by many large papillomatous projections rich in blood-vessels and young connective tissue and covered by a dense uniform layer of epithelium. Near the surface and in the depths deposits of lime are seen. In a few places the earliest stages of bone formation are seen, small islands of deeply-staining tissue arranged about cells in a trabeculated fashion. The adherent omentum contains many blood-vessels.

It remains for the future to determine the practical possibilities of fascia transplantation into vesical defects. The procedure may prove of value in some of the difficult problems of bladder surgery: vesical exstrophy, closure of defects after extensive resection, large vesicovaginal fistulæ, etc.

The process of tissue repair after experimental fascia replacement of bladder defects is of considerable interest. In the first place, it is adequate. Granulation tissue disappears soon after operation, fusion between the tissues of the defect and those of the bladder-wall is complete, epithelial overgrowth is complete at an early stage. The newly formed bladder-wall is as strong as or stronger than the remainder, contracts to an insignificant extent (if at all), does not lead to the formation of vesical calculi. These characteristics are quite uniform throughout all

the experiments. I wish to dwell upon two remarkable developments noted in the processes of tissue repair; bone formation in the defect and smooth muscle growth across the defect.

It is out of place to enter here into the whole question of the tissues required for bone development. That previous bone or periosteum is not necessary for the formation of new osseous tissue, was, of course, demonstrated by finding such tissue developed in situations far removed from the skeletal system. The experiments I have reported show clearly that the bone deposits occurred with concretions of lime as their beginnings, without any relation to blood-vessels, or to any of the tissues of the adjoining bladder-wall. Except for the necessary nourishment to the tissues repairing the vesical defect, it might almost be said that the development of bone took place, in this situation, outside the body. This is further emphasized by the fact that the deposit of bone was invariably limited to the site of the defect. The suggested possibility that fascia, genetically related to bone, was transformed into that tissue, is manifestly invalidated by the fact that lime deposits and bone formation appeared when fat was transplanted. Furthermore, it is to be noted that the fascia degenerates at an early stage, before the bone development is well on its way.

The evolution of bone in these experiments can be explained, therefore, only by the metaplasia of any connective tissue occupying the defect. That it was a development that may, in a sense, be termed "normal" for the existing conditions, is shown by its presence in every experiment. The reasons for, and the way in which, bone is laid down appear to me to be as follows: The tissue occupying the defect is constantly being subjected to great tension. The defect being too large to permit obliteration, reinforcement for the tissues filling the gap is desirable. A favorable opportunity to obtain reinforcement exists potentially in the presence of calcium salts in solution in the urine. These are laid down on the surface and are taken up in the depths of the transplant by imbibition. The lime deposits stimulate the surrounding connective tissue chemically or physically (or chemicophysically) to build up the most powerful barrier. Bone deposits are the result, with lime salts as their actual nuclei or their centers of stimulation. It is in this way that the microscopic findings in the experiments are best understood. Furthermore, one can realize why the astonishingly early development of bone was not a degenerative phenomenon.

The periosteum-like layer ensheathing the bone plaques can be accounted for satisfactorily on the theory of metaplasia of adjoining connective tissue, and similarly, metaplastic changes in connective tissue included between bone trabeculæ will explain the development of bone-marrow. However, the appearance of cartilage in one experiment cannot be accounted for readily in this way. The fact that cartilage developed only once appears to require, in itself, a different hypothesis. It is true that the appearance of the large deposit of cartilage, situated in a cup-like hollow in the bone, may be ascribed to metaplasia of connective tissue filling the cavity. The suggestion is evidently forced, however, for hollows in the other specimens of bone do not reveal cartilage. Furthermore, it cannot account for the scattering of the cartilage-cells in the adjacent bony mass and, above all, for the scattering of islands of cartilage-cells at widely separated points throughout the bone plaque. An adequate explanation cannot be offered. There appear to be only two possibilities; either bone was converted into cartilage or cartilage into bone. The latter would, of course, be in accord with a widely held view, but is not quite adaptable to the findings. Cartilage was not laid down in any of the other experiments, and in this specimen does not present the picture seen when cartilage is being replaced by bone. In support of the opposite hypothesis, it might be urged that, in the specimen in question, the sharp projecting prongs of bone at the end of the plaque made friction with the adjoining bladder-wall; in an effort to overcome this the development of cartilage was in the nature of a closely related tissue adaptation of the active growth of bone. Even if this were true, however, it does not account for the islands of cartilage scattered in the bone. The best suggestion that can be offered

at the present time is that, in this experiment, cartilage was orginally laid down, as in the embryo, and that it was gradually replaced by bone, as in postnatal life.

The presence of muscle bridging the defects will now be considered. I believe that the specimens offer conclusive evidence of the regeneration of smooth muscle. This question has been discussed for many years. The presentation of arguments based on the work that has been done in the past would lead too far afield. It will suffice to say that the generally held view at the present time is that smooth muscle regenerates little or not at all.

The large defects that were made in the bladder offered an unusual opportunity to investigate the question anew. The tissue found in the defects was undoubtedly smooth muscle.[1] It was characteristic in staining qualities, in the shapes and arrangement of the cells, in the long narrow nuclei; and was continuous with the smooth muscle of the bladder-wall on either side of the defect. The development of the smooth muscle in the defect can be traced in the chronological arrangement of the experiments. In examinations soon after operation, practically the whole muscle-wall stopped abruptly at the margin, only a few fibers extending short distances into the defect. At later stages bundles of muscle extended well into the defect, to make a neat, thin, continuous layer of muscle or an irregular, ill-defined layer of interlacing bundles in the latest stages. It is certain that the defects contracted little if at all, and that strips of muscle were not left attached when the defects were made. Only by the development of new muscle-bundles can the layer of smooth muscle found across the defect be explained. Evidences of smooth muscle regeneration were seen after defects made in some of the other hollow viscera but, because they were inconclusive, no further reference need be made to them.

2. TRANSPLANTATION OF FASCIA INTO URETHRAL DEFECTS

The experimental work of Kostenko and Rubaschew indicates that fascia transplantation *over suture lines* in the ureter is not a reliable procedure, for leakage of urine followed in several instances. In one experiment, however, at which an end-to-end anastomosis of the divided ureter was made and surrounded by a cuff of fascia, it was found that the suture lines in the ureter had separated and that the fascia was the only barrier to successfully prevent the escape of urine. Clinically, however, a case was reported by these authors in which fascia placed over the sutured ureter (after removal of a calculus) did not prevent leakage.

The clinical problem of replacement of ureteral defects has not been solved. Nephrectomy must be performed if end-to-end suture is impossible and the upper end of the divided ureter cannot be implanted into the bladder. It is, therefore, surprising to find that so few experimental efforts have been made in this field. Owing to the resistant qualities of fascia, I believe that tubes made of this material might satisfactorily replace ureteral defects. Although there is not a single completely successful experiment to support the view that the procedure is practicable, and possibly clinically applicable, it is nevertheless, maintained, for the failures encountered depended on several factors that can be eliminated: (1) The ureters in the dog are of very small caliber; (2) faulty technique; (3) inability to obliterate permanently the "dead space" left after extraperitoneal exposure of the ureter. Additional experience may obviate these difficulties.

The best experimental results were obtained when a tube of fascia was first constructed around a glass rod in the thigh and was transferred to the ureteral defect two weeks later. In three experiments in which this was done, there was absolutely no leakage. Unfortunately the animals died too soon after operation (one from hæmorrhage, two from unknown causes), to determine if a permanently satisfactory result would have been obtained. The description of a single experiment will suffice to illustrate the technique.

Experiment Dog 342. Male, medium size. *First operation,* June 10, 1914. Fascia lata exposed in left thigh. Glass rod, smooth at both ends.

[1] Drs. Clarke, McWhorter, and Sharp, of the Columbia University, College of Physicians and Surgeons, kindly corroborated this statement.

approximately the diameter of the ureter, dipped in vaseline, placed over fascia. Latter incised on either side of rod, sutured snugly over it with very fine silk. Subcutaneous tissue and skin sutured.

Second operation, June 25. Left ureter exposed extraperitoneally by an incision through the lateral abdominal musculature. Middle part of ureter isolated, the vessel running alongside ligated above and below, 5 centimeters resected. Field of first operation exposed. Glass rod found loose, and removed. Fascia tube made complete by freeing both ends and ligating them. The tube then measured 7 centimeters. Small slits were cut into it at each end near the ligatures. The ends of the ureters were drawn through the slits and fastened within the tube, as seen in the accompanying diagram. Layer suture of the wound.

Postoperative course. Nothing abnormal noted. Four days after operation the dog was found dead in his cage.

Postmortem examination. Cause for death could not be ascertained. Wound solid, no leakage of urine. Peritoneal cavity intact. Kidneys negative. Ends of ureters firmly fixed in fascial tube. Probe passed readily from above through ureter into the tube and the lower end of the ureter. Water injected from above passed through without difficulty.

The results of all the experiments in which the fascial tube was built around the ureteral defect were unqualified failures. Death followed either from leakage and infection or from hæmorrhage into the wound. In one instance the hæmorrhage was only moderate and the anatomical result of the operation was satisfactory. This experiment will be reported and the technique of construction of a fascial tube *in situ* will be described.

Experiment Dog 266. Operation, April 10, 1914. Extraperitoneal exposure of middle portion of the left ureter. Isolated, 2½ centimeters excised. Vessels accompanying ureter not ligated to avoid compromising the lumen. Anterior lips of cut ends of ureter slit up a few millimeters. Sheet of fascia lata of suitable size, held by tension sutures, placed under the defect. Posterior lips of ureter ends fixed to fascia at two points each, by passing double-threaded sutures and tying knots on outside of fascia. The upper pair of guide sutures in the fascia brought together, then the lower pair. The two edges of the fascia then sutured (continuous fine silk) to make the tube. Before latter was complete, above and below, double-threaded sutures were passed from anterior lips of ureter ends through fascia, knots on the outside. The sutures were so placed that, when drawn taut and knotted, the cut ends of the ureter would be held wide open. The fascia tube suture completed above and below by being carried over ureter and sutured to its wall. Additional stitches all around from end of fascia tube to ureter wall, fixed the tube firmly in place. Layer suture of the wound.

Postoperative course. Condition good immediately after operation. Gradually deteriorated. Death April 14.

Postmortem examination. Moderate hæmorrhage into the extraperitoneal space. Source apparently the vessel accompanying ureter. No blood in the urine-filled bladder. Anastomosis intact. Probe and fluid pass through readily from above downward. Viewed from within, the lips of the ureter fit snugly against fascia tube.

3. Fascia Transplantation into Œsophageal Defects

Brief reference has already been made to the experiments performed by Koenig and by Hohmeier, in reinforcing suture lines of the œsophagus. Kostenko and Rubaschew reviewed their work in a considerable number of experiments. They found that the transplant could be depended upon almost invariably to prevent leakage from such suture lines. On the other hand, necrosis and perforation of the fascia followed all their attempts to replace appreciable defects — 2 x 2 centimeters or more — of all the layers of the organ.[1] There were *occasional* successes in their efforts to bridge very small œsophageal fistulæ by fascia transplants; they were found to depend upon obliteration of the defect and not upon upbuilding of new tissue in it. All these observations have no further practical significance than to suggest that suture lines in the œsophagus can be reinforced satisfactorily by fixing fascia strips over them. In short, it was as incorrect to say that experimental defects of the œsophagus have been satisfactorily bridged by fascia as it was to make such statements concerning vesical defects.

Despite these experiences, it was thought that, with the modifications of technique that have been described, large defects might be successfully replaced by fascia transplants. It was essential, however, that little or no œsophageal stenosis should follow; otherwise the procedure would be no better, less desirable, in fact, than ordinary suture or plastic methods. Only a few experiments were necessary to demonstrate that large defects,

[1] Histological examinations are not reported in any of these experiments.

involving as much as the entire anterior aspect of the œsophagus, could be satisfactorily bridged in this way. The results were good anatomically and functionally. Slight stenosis was observed in an experiment concluded two weeks after operation; this was less evident in an experiment ended three weeks after operation, and was almost imperceptible four weeks after operation. In view of the more infected state of the animal œsophagus, the unavoidable movements of the head and neck after operation, and the necessary administration of nourishment by mouth soon after operation, it appears correct to believe that the expectation of success after fascial transplants into œsophageal defects in the human subject can be even greater than in the experiment. The present-day treatment of small œsophageal fistulæ is simple and efficient. The attempt to close larger defects (as after excision of a diverticulum, sloughing from impacted foreign body, etc.) involves complicated plastic procedures, the average results of which cannot be termed very satisfactory. It remains for the future to determine if fascia transplantation, technically very simple, can offer better results.

The experimental results I have obtained are seen in the descriptions that follow. Granulation tissue appeared on the surface of the transplant soon after operation. In the later stages the defect was found solidly filled by connective tissue (representing the altered fascia), partly contracted, and entirely covered by epithelial overgrowth.

Experiment Dog 157. Female, medium size. Operation, March 1, 1916. Longitudinal incision slightly to left of midline of neck. Musculature split over trachea. Latter retracted. Œsophagus exposed and isolated about 5 centimeters below level of thyroid cartilage. Left vagus dissected from wall and drawn aside. Defect 4 x 2½ centimeters made in anterior wall, long axis in that of œsophagus. Mucus sponged away. Bleeding vessels not ligated. Fascia lata, slightly larger than defect, sutured in place. A few reinforcing sutures. Layer suture of wound.

Postoperative course. Fluid diet for first week. Animal considerably emaciated at end of that time. Improved promptly with soft diet. Chloroformed March 17, sixteen days after operation.

Postmortem examination. Periœsophageal connective tissue extensively adherent at site of operation. In this situation œsophageal wall felt infiltrated. No evidence of stenosis with œsophagus *in situ*. After removal of specimen and marked distention with fluid, slight stenosis noted at level of transplant.

Inspection of interior: many silk sutures hanging free. After their removal a central irregular elevation of tissue noted at site of transplant. Surrounding it a narrow, smoothly covered hollow. Beyond that the mucous membrane, thrown up in definite ridges toward the defect, merging gradually into the normal œsophageal lining in the opposite direction. The whole patch of abnormal tissue measured 3 x 1½ centimeters.

Microscopic examination. Surgical Pathology No. 3884. The transplanted fascia is broken up into bundles undergoing hyaline degeneration. On both sides of the defect these fuse with the mucosa and muscularis, the physical union evidently being very close. There are many blood-vessels (filled with red cells) in the fascia layer about the middle, fewer toward the periphery, of the defect. The free surface of the fascia is covered by a thick layer of organizing granulation tissue. Over this the epithelium overgrowth is complete. The layer composed of granulation tissue plus epithelium is raised in villus-like folds, the free ends of which appear very fragile (absent in several places in the stained specimens). The deep surface of the transplant is covered by a thick layer of young connective tissue.

Experiment Dog 150. Male, fair size. Operation, February 23, 1916. Œsophagus exposed as in previous experiment, at a somewhat higher level. Left thyroid lobe retracted, inferior thyroid vessels ligated. Left vagus and carotid vessels isolated and drawn aside. Section of lateral wall of œsophagus, 2½ x 3½ centimeters, removed. Replaced by fascia lata. Several reinforcing sutures. Wound closed in layers.

Postoperative course. Fluids for one week; soft diet thereafter. Emaciation, considerable at the outset, never disappeared. Animal in very good condition, however. Chloroformed March 17, twenty-three days after operation.

Postmortem examination. Slight puckering and stenosis of œsophagus at site of transplantation. Surrounding connective tissue adherent. Œsophageal wall felt firmer here than elsewhere. Stenosis evidently very slight, as tested by water distention.

Inspection of interior: Silk sutures hanging loose, were removed. Irregular ridge, 2½ centimeters long, narrow for the most part, at site of defect. It is elevated into small knobs here and there. Mucous membrane appears to stop at the bottom of the ridge, the covering of the latter being a smooth, translucent, thin layer of tissue of distinctly different appearance from normal mucous membrane.

Microscopic examination. Surgical Pathology No. 3883. The defect is partly drawn together at the free surface, where it is covered over by a complete layer of epithelium thrown into low ridges.

The defect is drawn together to a lesser degree in the depths, where it is filled by a thick layer of connective tissue barely recognizable as fascia undergoing hyaline degeneration and fibrous tissue replacement. Muscle bundles from the œsophageal wall are numerous and neatly arranged toward the margin of the defect, interlace irregularly and gradually thin out toward its middle. Fusion of muscle and connective tissue. There are many large blood-vessels throughout the tissue filling the defect, but no granulation tissue is to be seen.

Experiment Dog 143. Male, good size. Operation, February 16, 1916. Exposure of lower third of œsophagus. Isolated from trachea and left vagus. Section of anterolateral wall 3½ x 2 centimeters removed. Replaced by fascia in the usual manner. No reinforcing sutures. Layer suture of wound.

Postoperative course. Fluids for one week, soft diet thereafter. Emaciation, extreme at outset, did not entirely disappear. General condition excellent, however. Chloroformed March 17, one month after operation.

Postmortem examination. Thin adhesions to site of operation, which is otherwise indistringuishable. No sign of stenosis with œsophagus *in situ*. When removed and submitted to maximal fluid distention, very slight stenosis is visible. Viewed from the interior, an almost imperceptible, slightly elevated cicatrix 2½ centimeters long, a few millimeters to 1 centimeter wide; covered by smooth, shining tissue continuous with œsophageal mucous membrane.

Microscopic examination. Surgical Pathology No. 3882. Complete epithelial overgrowth. The defect is filled by a thick mass of connective tissue in which a fascial structure is not discernible. Muscle-bundles extend into and fuse with this layer, thinning out as the center of the defect is approached. The tissues of the defect pass over, by insensible gradations, into those of the œsophageal wall, only the mucous glands in the latter suggesting the line of demarcation.

4. TRANSPLANTATION OF FASCIA INTO GASTRIC DEFECTS

Attention has been called to the attempts by various experimenters to support suture lines of the stomach by transplanting strips of fascia over them. The experiments have not demonstrated clearly that this procedure offers definite assurance of additional reinforcement. Attempts to replace all the layers of the stomach have failed invariably, even when the defects were very small.

These attempts were repeated by me with the described modification in technique, in a number of experiments, because there appeared to be some possible clinical applications in gastric surgery if the experiments proved successful. Failure followed in every instance. Perforation through the necrotic transplant always occurred, no matter what technique was employed. Apparently the transplanted fascia was attacked by the gastric juice and its disintegration promptly followed. This view was supported by the fact that the perforation was almost invariably a smaller or larger one near the center of the transplant, and not a separation of the suture lines. Indeed, intact suture lines between stomach and transplant, with relatively intact fascia adjacent to them, were encountered in several of the experiments. The details of all the experiments are unnecessary. The following will serve as examples:

Experiment Dog 136. Operation, December 24, 1913. Defects 3 x 2 centimeters near pylorus, sheet of fascia from the abdominal wall, slightly larger, implanted into it. Death within twenty-four hours from perforative peritonitis. Transplant almost completely gone. Only a thin fringe found attached at the suture line.

Experiment Dog 73. Operation, November 12, 1913. Defect 4 x 3 centimeters on anterior surface of stomach. Excess mucosa removed. Fascia transplant slightly larger. Several reinforcing sutures. Death two days after operation. Small perforation through center of transplant, generalized peritonitis. Omentum adherent to fascia around the perforation. Viewed from within, smooth, firm union of gastric wall and transplant. Mucosa congested near the suture line.

Finding these efforts to replace gastric defects by fascia quite futile, it appeared of interest, in relation to experiences in the human being, to inquire if gastro-enterostomy would in any way influence the result. The most generally practiced operation for perforated gastric ulcer is suture of the ulcer and gastro-enterostomy. Exclusion of the pylorus is added by some surgeons. On the other hand, some observers believe that gastro-enterostomy is not essential or even desirable in the treatment of perforated gastric ulcer, especially because it has been demonstrated that gastro-enterostomy does not deflect the gastric contents from the site of a sutured ulcer near the pylorus. Turning to the experiments I performed, they consisted in the addition of gastro-enterostomy,

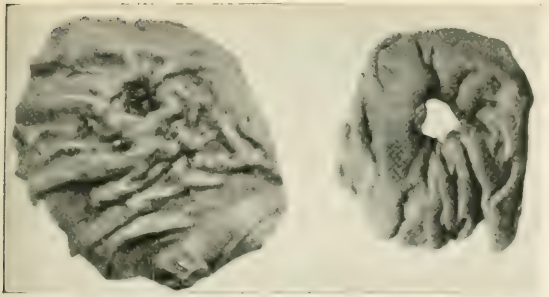

Fig. 29, A (at left). Small perforation through center of fascia transplant in defect of stomach indicated by probe. B. Large perforation in transplant into gastric defect, firm union between remnant of fascia and adjoining wall of stomach. (The cross hatching is due to gauze against which the specimen was pressed.)

with and without pyloric exclusion, to the fascia replacement of defects near the pylorus. They demonstrate clearly that gastro-enterostomy does play an important rôle, has a profound influence upon the result, for the fascia transplant healed in place invariably when gastro-enterostomy was added. Exclusion of the pylorus was manifestly not a factor, for the results were entirely satisfactory without any attempt at its practice. The contrast between the previous group of experiments, in which failure followed every effort at fascia replacement of gastric defects, and this group, in which fascia replacement was always successful when gastro-enterostomy was added, is very impressive.

Two illustrative experiments follow, one with and one without pyloric exclusion. A remarkable feature of the first was the formation of true bone in the tissues at the site of the defect. This is merely mentioned here, for the question of bone formation was considered in detail in the section devoted to fascia transplantation into bladder defects. The conditions were analogous except that, in the bladder experiments, the necessary calcium salts were of course much more readily accessible.

Experiment Dog 207. Large male. Operation, April 5, 1916. Incision in right hypochondrium. With its center about 6 centimeters from the pylorus an oval defect 4 x 2½ centimeters was made. Defect replaced by a slightly larger sheet of fascia, usual technique, six reinforcing sutures. No loop gastro-enterostomy.

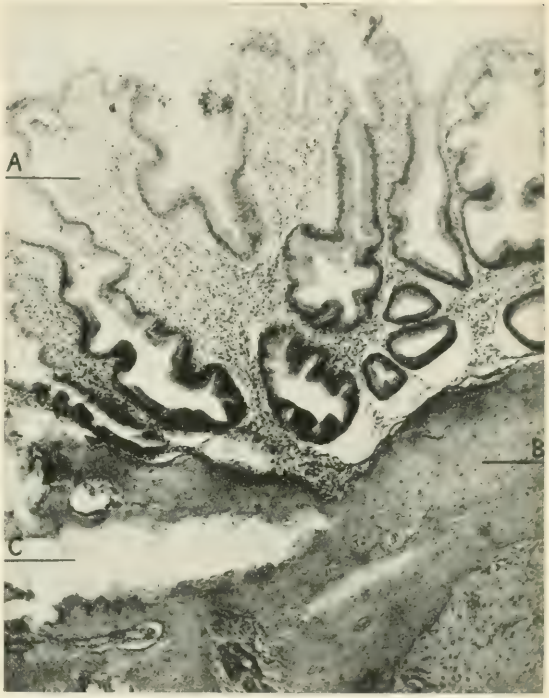

Fig. 30. Pathology No. 4007. Eight weeks after fascia transplant into defect of stomach. Photograph from periphery of filled defect. *A*, Well-developed mucosa resting directly on bone plaque, *B; C*, artefact.

Postoperative course. Fluids for one week, soft diet for two weeks, ordinary food thereafter. Animal always in splendid condition. Chloroformed June first, eight weeks after operation.

Postmortem examination. Gastro-enteric stoma and pylorus open. Omentum adherent at site of transplant so that the external surface could not be seen. No sign of weakness upon extreme fluid distention of the clamped-off stomach. Viewed from within, the field of operation was a somewhat depressed area about 2 x 3 centimeters, smoothly covered over by gastric mucous membrane.

Microscopic examination. Surgical Pathology No. 4007. Intimate fusion between the tissues occupying the defect and the adjoining gastric wall. No evidence of the transplanted fascia as such. It is replaced by a closely woven mass of connective tissue. Embedded near its free surface is a macroscopic plaque of bone with many small marrow-spaces, numerous osteoblasts, occasional osteoclasts, and a fairly well-developed limiting, periosteum-like sheath. The deposit of bone is sharply limited to the site of the defect. The free surface of the latter is completely covered by the overgrown gastric mucosa. This is seen in varying stages of development, from the mature layer at the periphery of the defect, to the low, irregularly laid down villi toward the center.

Fig. 31. Pathology No. 4007. Eight weeks after fascia transplant into defect of stomach. Photograph from region toward center of defect. *A*, *A*, Incompletely developed mucosa; *B*, bone plaque with periosteum-like layer, *C*, *C*; *D*, connective tissue in remainder of defect.

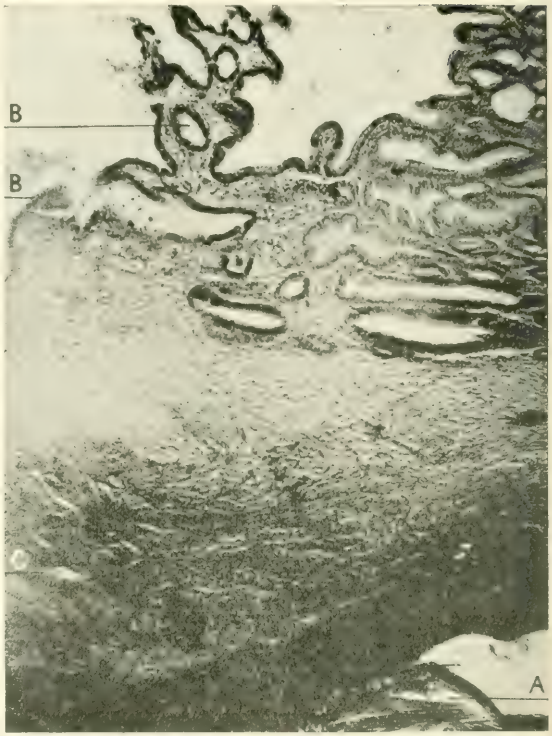

Fig. 32. Pathology No. 3900. Fifteen days after fascia transplant into defect of stomach. *A*, Silk suture indicating line of transition; *B*, *B*, atypical mucous membrane growing over organized granulation tissue of defect; *C*, degenerating fascia.

Experiment Dog 166. Good sized male. Operation, March 8, 1916. Epigastric incision. About 5 centimeters from the pylorus a defect 2 x 3 centimeters was made. Excess mucous membrane excised. Replaced by a slightly larger sheet of fascia with usual technique. To make it more secure, the edge of the fascia, wherever it projected between the sutures, was attached to the adjoining gastric serosa by a second tier of sutures. Ordinary short loop gastro-enterostomy. Pylorus ligated with stout silk. Layer suture of the wound.

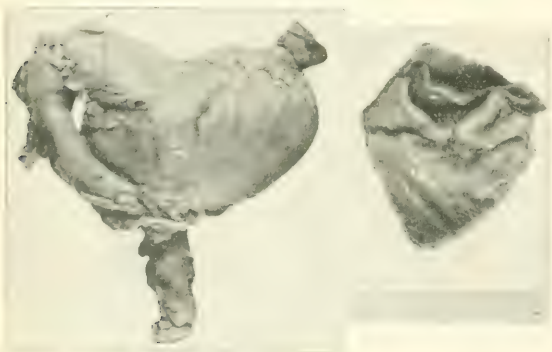

Fig. 33. Fifteen days after fascia transplant into gastric defect. A (at left). Arrow points to site of transplantation, to which an irregular patch of omentum is adherent. The gastro-enterostomy and incomplete pyloric occlusion are seen. B. Appearance of interior of stomach at the transplanted area.

Postoperative course. Fluids for one week, soft diet thereafter. Animal in excellent condition. Chloroformed March 23, fifteen days after operation.

Postmortem examination. Pyloric occlusion incomplete. Gastro-enteric stoma patent. The extreme left margin of liver, surrounded by a thin strand of omentum, adherent at site of transplantation. After their detachment, the gastric wall underneath was found to be the seat of a firm plaque, not very sharply circumscribed, about 2 x 2 centimeters.

Microscopic examination. Surgical Pathology No. 3900. Firm union between tissues filling defect and adjoining stomach-wall. The transplanted fascia has undergone considerable *hyaline degenera-*

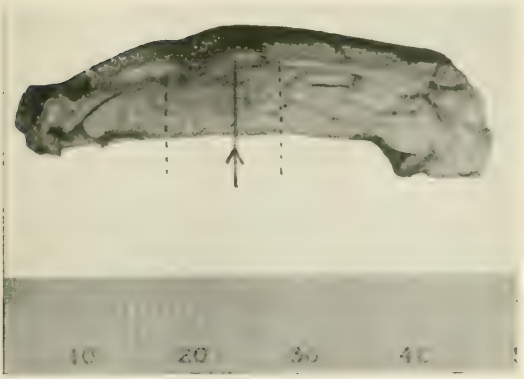

Fig. 34. Pathology No. 2685. Cross section of small intestine through transplant, one month after operation. Arrow points to the tissue occupying the defect, the dotted lines indicating the abrupt termination of the intestinal wall at the defect.

Fig. 35. Pathology No. 2685. One month after fascia transplant into defect of small intestine. *A*, Organizing granulation; *B*, *B* margin of wall of intestine, indicated on one side by silk suture, *C*; *D*, *D*, remnants of degenerating fascia; *E*, artefact.

tion. Its deep surface is covered by a layer of connective tissue, to which omentum is adherent. Its free surface is covered by a layer of organizing granulation tissue, over which the gastric mucous membrane has in part grown, in an atypical fashion.

5. FASCIA TRANSPLANTATIONS INTO DEFECTS OF THE SMALL AND LARGE INTESTINE

Reinforcement of suture lines in the intestinal wall has been attempted, both clinically and experimentally, with varying results that have already been mentioned. No effort has been made to replace actual defects in either the large or small intestine. For the reasons that have been advanced in the first part of this paper, it was of interest to determine if such procedures could be successfully carried out. The following results were obtained: Transplants into defects in the upper part of the small intestine generally failed. Small transplants in the lower part of the small intestine were often successful, but the replacement of larger defects not infrequently failed. On the contrary, fascia implantation into these larger defects in the large intestine succeeded in two out of three experiments. In short, there have been failures after transplants into defects of small and large intestine of about the same size as those that have been successfully bridged. These results indicate that, though occasionally successful, fascia transplantations into intestinal defects is not a very reliable procedure. The results are not comparable with those obtained in the œsophageal and vesical defects or in the tracheal defects to be described. Yet the possible practical application must be considered in some of the difficult problems that are encountered in urgent abdominal surgery.

The technique employed was the same as in the other groups of experiments; implantation *into* and not *over* the defects. Microscopic

Fig. 36. Pathology No. 2685. One month after fascia transplant into defect of small intestine. Showing epithelium growing over granulation tissue and transition from intestinal wall to tissues of defect.

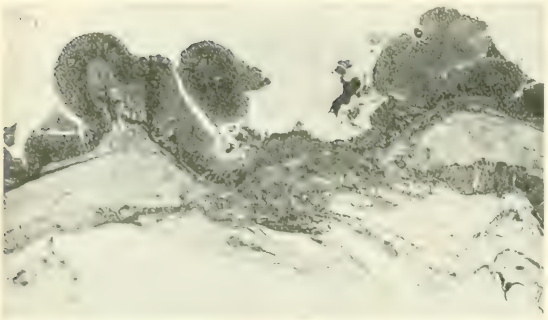

Fig. 37. Pathology No. 2932. Five weeks after fascia transplant into defect of large intestine.

examinations revealed some shrinkage of the defect but very slight or no stenosis was visible in the gross specimens. As will be seen in the following experiments, granulation tissue appeared on the free surface and between the bundles of the disintegrated transplant. The intestinal mucosa grew in part over this granulation tissue but in no instance completely across, in the relatively limited periods of observation after operation.

Experiment Dog 63. Small male. Operation, November 5, 1913. Median epigastric incision. Loop of small intestine, about 8 centimeters above ileocolic junction, drawn out of wound, intestinal clamps applied above and below. The intestinal wall contracted to a flat ribbon-like band, so that determination of size of defect was difficult. An elliptical section, 3 x 1½ centimeters removed, the long axis in the long axis of the intestinal canal. Slightly larger sheet of fascia from the abdominal wall sutured into defect in the usual manner. Slightly overhanging edges of transplant attached to adjoining intestinal wall by a number of Lembert sutures. After removal of clamps, no leakage. Spasm of intestine disappeared and actual defect measured. It was 2¼ x 1¾ centimeters, opposite the mesentery, and involved more than half the circumference of the bowel. Suture of the abdominal incision.

Postoperative course. Temperature between 101° and 103° for four days, normal thereafter. No evidences of peritonitis. Animal in good condition. Sacrificed with chloroform December 1, four weeks after operation.

Postmortem examination. No signs of peritonitis. Omentum adherent to intestine in region of operation. No evidence of stenosis upon inspection or distention of the bowel with water. No bulging at field of operation with considerable water pressure. Inspected from within, a slight constriction of the lumen appears to exist. The site of transplantation slightly elevated, appeared smooth and apparently covered in part by mucosa.

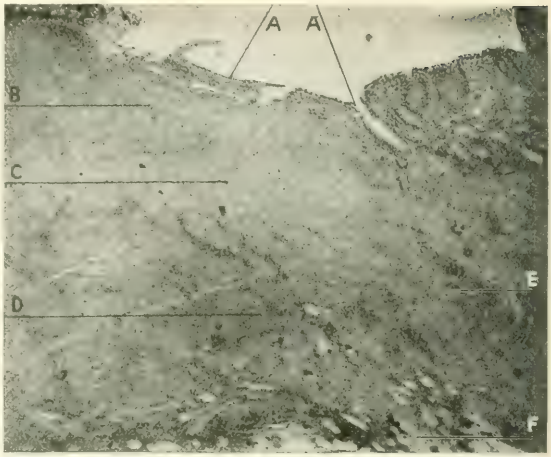

Fig. 38. Pathology No. 2932. Five weeks after fascia transplant into defect of large intestine. *A*, Epithelium covering organized granulation tissue, *B; C*, connective tissue intermingled with remnants of fascia, *D; E*, muscle fibers extending into defect; *F*, omentum.

Microscopic examination. Surgical Pathology No. 2685. Defect smaller than at operation, its free surface occupied by organizing granulation tissue. This goes over, in a relatively sharp line, into neighboring muscularis, submucosa, and mucosa. Small fragments of transplanted fascia about silk sutures in the depths. Adjacent to serosa is a thick layer of fatty tissue (omental adhesion). At its free surface the granulation assumes a mushroom-like appearance. Intestinal epithelium extends over its lateral aspects, ending on each side in a single layer of cells.

Experiment Dog 198. Female, medium size. Operation, February 18, 1914. Incision in hypogastrium. Some free fluid in abdomen (the result of an abdominal operation performed three weeks before?). Large intestine about 10 centimeters from the anus delivered into wound, semisolid fæces massaged out, clamps applied. Circular section of the wall 2¼ x 2¼ centimeters removed, replaced by slightly larger sheet of fascia lata. Redundant mucosa not excised. A number of reinforcing Lembert sutures were required, comprising practically a second tier of sutures. Clamps removed, fascia bulged outward, no leakage. Layer suture of abdominal incision.

Postoperative course. Normal temperature on the second day, no subsequent abnormal manifestations. Stools as before operation. Animal sacrificed with chloroform because of beginning distemper on March 24, five weeks after operation.

Postmortem examination. Omentum broadly adherent to field of operation so that region of defect cannot be seen. No evidence of constriction of the lumen, as tested by water-pressure. With same test no sign of weakness of bowel at site of transplantation. After washing away fæces the appear-

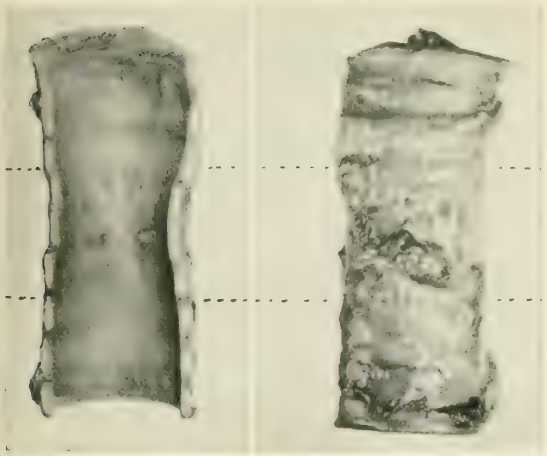

Fig. 39. Pathology No. 3840. External and internal views of trachea eight weeks after fascia transplant into defect involving two rings. Site of defect between the dotted lines. Hardened specimen, exaggerating distortion.

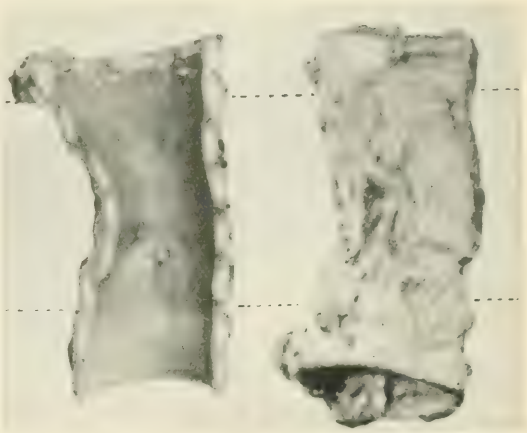

Fig. 40. Pathology No. 3841. External and internal views, eight weeks after fascia transplant into large tracheal defect involving three rings. Site of defect between the dotted lines. Hardened specimen, exaggerating distortion.

ance of the field defect was that of a somewhat depressed ulcer healed down to a very small area in the center.

Microscopic examination. Surgical Pathology No. 2932. The exact margins of the original defect cannot be determined, but there does not appear to be any great shrinkage in size. Granulation tissue fills the free surface of the defect and extends into a thick, closely-woven layer of connective tissue (scar tissue) situated opposite the mucularis and serosa. Bundles of muscle-fibers, principally from the inner muscular layer, extend across the position of the defect, fusing with the scar tissue. The surface of the granulation tissue is covered by intestinal epithelium in several layers toward the periphery of the defect, in a single layer almost completely over the middle. The omental adhesion is represented by a broad layer of fatty tissue rich in thick-walled blood-vessels.

6. FASCIA TRANSPLANTATION INTO TRACHEAL DEFECTS

The first experimental work in this field was performed by Hohmeier. He found that fascia could be successfully transplanted over very small tracheal defects (one-half to three-quarters of a square centimeter) and that flat epithelium grew in part over the granulation tissue occupying the surface of the defect. Davis, in replacing similarly small (8 x 8 millimeters) defects found that complete epithelial overgrowth (type of cells not mentioned) developed. Larger areas (less than 2 x 2 centimeters) were replaced by fascia in a series of experiments reported by Kostenko

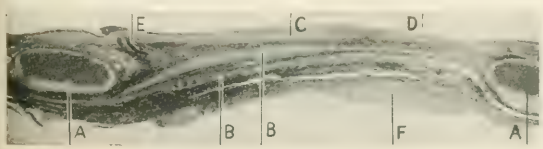

Fig. 41. Pathology No. 3841. Longitudinal section through trachea at site of transplant. *A*, *A*, Cross sections of cartilage rings at both sides of defect; *B*, *B*, the two layers of fascia lata; *C*, *F*, layers of connective tissue covering fascia; *D*, layer of epithelium; *E*, silk suture.

Fig. 42. Pathology No. 3841. Enlargement at *E* in Fig. 41. *A*, continuous layer of ciliated epithelium, the cilia very indistinctly shown; *B*, silk suture; intimate fusion of degenerating fascia, *C*, *C*, *C*, with connective tissue, *D*, around cartilage.

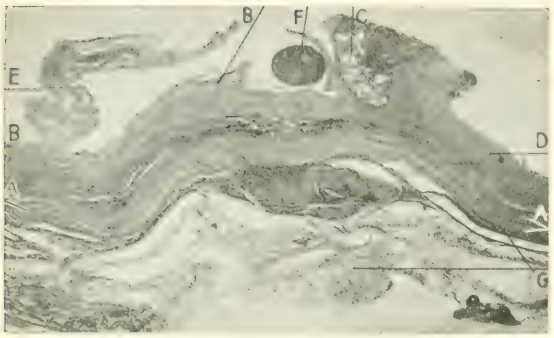

Fig. 43. Pathology No. 3153. Five months after fascia transplant into pleurothoracic defect. *A*, *A*, The two layers of altered fascia bridging defect; *B*, *B*, parietal pleura with layer of mesothelium spread over free surface of defect; *C*, lung adherent, chiefly by *D*, thickened pulmonary pleura; *E*, villous projection of regenerated pleura; *F*, artefact; *G*, subcutaneous tissues.

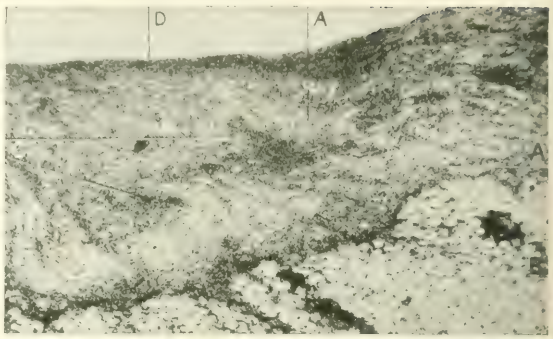

Fig. 44. Pathology No. 3047. Two weeks after fascia transplant over defect of lung. *A*, *A*, layer of altered fascia intimately adherent to lung, *B*; *C*, round-cell invasion; *D*, smooth free surface of transplant.

and Rubaschew; here, however, overgrowth of tracheal epithelium was never seen.

Fascia replacement of minute tracheal defects has little practical importance, since ordinary surgical methods accomplish this satisfactorily. If the work of Kostenko and Rubaschew is accepted, the replacement of somewhat larger defects by fascia is undesirable because the exposed granulating transplant would be apt to lead to complications. Clinically the cure of large defects of the trachea is as yet an incompletely solved problem. Complicated plastic operations have been devised in the effort to radically close these fistulæ. Flaps from the sternum or clavicle have been turned upward to supply the necessary rigid layer of tissue in the gap. For tracheal fistulæ at a high level, flaps from the thyroid or cricoid cartilages have been turned downward. The results that have been obtained by various methods will be detailed later; it will suffice to say here that failures have followed all the advocated procedures.

If experimental transplantation of fascia into large tracheal defects proved completely successful despite the difficulties that exist in the care of animals after such operations, it could be said that the application of this procedure to the human being offers the most logical method of treating such large tracheal defects. In the experiments to be described it was found that very large tracheal defects could be replaced satisfactorily by transplanting fascia *into* the defect. Very little stenosis followed. The ciliated tracheal epithelium grew completely over the transplant soon after operation. Both anatomically and functionally the results were well-nigh ideal. In my first experiment the transplant was sutured *over* the relatively small defect, after the method advocated by Hohmeier and others, and leakage and pretracheal suppuration followed. In all succeeding experiments larger defects were invariably successfully replaced, without any technical difficulty or postoperative complications, by fascia implantation *into* and not over them.

Experiment Dog 65. Female, medium size. Operation, December 14, 1915. Ether insufflation anæsthesia. Vertical incision over trachea, middle portion. Trachea exposed about five rings below cricoid by splitting the muscles. Anterior aspect isolated for a short distance. Quadrilateral section removed from front of tracheal tube measuring 1½ x 1½ centimeters. It involved removal of two rings. Fascia lata, slightly larger, sutured in place with usual technique except that the continuous suture took larger bites than usual in the tracheal wall, the stitches were somewhat closer together, and every third stitch was tied. Suture of pretracheal musculature and skin. Cotton, collodion dressing. No bandage.

Postoperative course. Uneventful. No subcutaneous emphysema. Primary union. Animal chloroformed February 8, 1916, eight weeks after operation.

Postmortem examination. Slight stenosis of trachea at site of operation. Small area of overlying muscle firmly adherent. The inner surface of the original defect is covered by a smooth shining layer of tissue continuous without line of demarcation

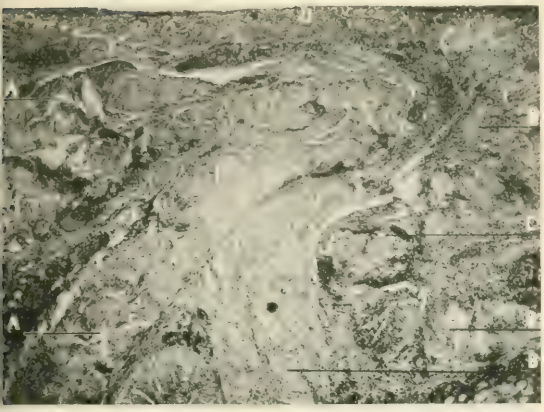

Fig. 45. Pathology No. 3048. Two weeks after fascia transplant into a pericardial defect. *A*, *A*, Folded end of degenerating transplant, firmly united to cut margin of pericardium, *B*, *B*, *B; C*, silk suture at site of junction; *D*, smooth layer of tissue on free surface of transplant.

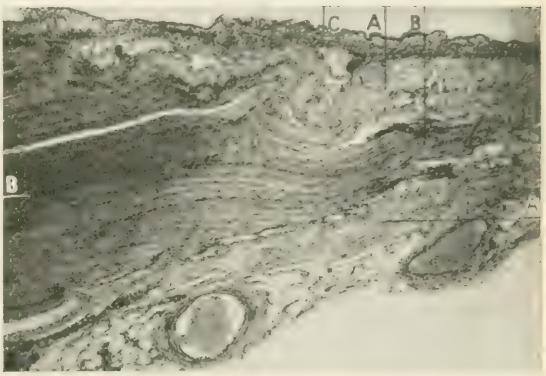

Fig. 47. Pathology No. 3206. Five months after fascia transplant into defect of diaphragm, showing the fusion between the altered transplant. *A*, *A*, and diaphragmatic musculature, *B*, *B*. In this section the continuous layer of pleura *C*, is well seen.

with the normal tracheal lining. The lines of silk sutures are seen shimmering through. By measurement between them very slight if any shrinkage can be determined. After specimen was hardened in formalin vertical section showed shining cut surface of fascia, covered on both sides by layers of tissue.

Microscopic examination. Surgical Pathology No. 3840. Characteristic structure of transplant remains, but there are evidences of hyaline degeneration throughout. Physical union between transplant and the pericartilaginous connective tissue is very intimate. The free surface of the transplant is completely covered by ciliated tracheal epithelium continuous with that beyond the site of the defect. A ridge in the epithelial layer represents the place at which overgrowth begins. The deep surface of the transplant is covered by a layer of thickly woven connective tissue. The cartilage rings at both sides of the defect are capped by masses of faintly staining, irregularly arranged cartilage-cells indicating budding or proliferation of the cartilage. These caps fuse with the ends of the transplanted fascia.

Experiment Dog 66. Medium sized male. Operation, December 15, 1915. Intratracheal anæsthesia. With same procedure as in previous experiment quadrilateral defect made in trachea included three rings in length and in diameter practically the entire anterior aspect of the organ. Defect measured 2½ x 2 centimeters. Fascia lata slightly larger, sutured in place as in previous experiment. To hold the transplant tense its margin was stitched to the adjoining surface of the overlying musculature in a few places. Layer suture of the wound.

Postoperative course. Uneventful. No subcutaneous emphysema. Animal sacrificed February 8, 1916, eight weeks after operation.

Postmortem examination. Slight stenosis of the trachea. No adhesions of overlying musculature. Silk sutures visible on external surface; by measurement between them slight shrinkage noted. Appearance of internal surface at site of defect identical with previous experiment — smooth shining layer of tissue continuous with tracheal mucosa.

Microscopic examination. Surgical Pathology No. 3841. The findings are practically identical with those in the previous specimen. The ends of the cartilage rings show active proliferation. Fusion between fascia and the tracheal tissues is complete, only the position of the silk sutures marking the

Fig. 46. Pathology No. 3206. Five months after fascia transplant into defect of diaphragm. *A*, Muscle of diaphragm at one margin of defect; *B*, *B*, layer of peritoneum (folded in the section) and *C*, layer of pleura spread over the free surfaces of the transplant.

Fig. 48. Pathology No. 3154. Six and one-half months after fascia transplant into a defect of the surface of the liver. *A*, *A*, Completely transformed fascia, recognizable as such in several places as at *B*. *C*, Surface of liver, smooth and intimately connected with the transplant. *D*, *D*, Islands of, and *E* individual liver-cells, scattered in connective tissue.

transition. Overgrowth of ciliated tracheal epithelium is complete. The characteristic appearance of the transplant is still moderately well preserved.

7. FASCIA TRANSPLANTS INTO PLEURAL DEFECTS

The first and most complete experimental work in this field was done by Kornew. He replaced pleural defects as large as 8 x 6 centimeters and found that, with little or no tension practically no changes in the structure of the transplanted fascia were observed, even after one year. It is to be noted, however, that, although the true fascial bundles remained unaltered, the interfascicular tissues did show distinct changes. This is significant, because it suggests ultimate conversion of the transplant into scar tissue. Kornew found a layer of flat mesothelial cells lining the pleural surface of the fascia. Adhesions between lung and transplant occurred very rarely.

The work of other experimenters need only be mentioned. All of Kirschner's experiments were failures, the animals dying of empyema. There were also many infections in Hirano's experiments, described in a very incomplete report. Adhesions between lung and pleura were encountered, but Hirano believed that these might have been avoided

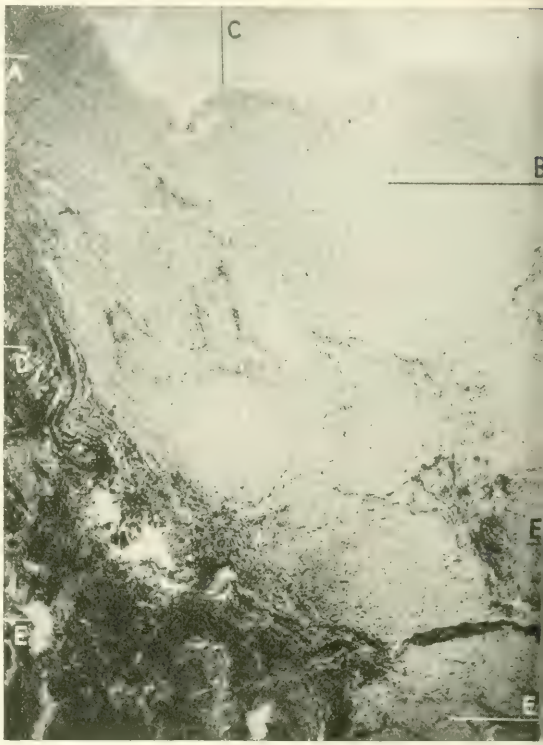

Fig. 49. Pathology No. 2747. Two months after fascia transplant into defect of spinal dura. *A*, Dura continuous with the thickened and greatly altered transplant; *B*, *C*, smooth free surface of transplant, mesothelial cells very indistinctly seen; *D*, silk suture at margin of defect; *E*, *E*, *E*, the spinal musculature, fused with the deep surface of the transplant.

by inducing and maintaining a closed pneumothorax.

Clinically, several cases of fascia transplantation into pleural defects have been reported. Payr's is perhaps the most interesting instance. After removal of a tumor of the chest-wall extensively involving the pleura, a large sheet of fascia was implanted into the defect. Upon examination six months later, a recurrence of the neoplasm was found, but the chest-wall was absolutely firm at the site of the transplant.

All previous experimenters considered it essential to suture the fascia transplant over the defect. The experiments I performed demonstrate that it can be satisfactorily implanted into the defect. In this situation two advantages are seen in the modification of technique. The ends of resected ribs are

not exposed intrapleurally, and friction between them and the transplant is eliminated. These advantages were evident to others (Hirano, Henschen), but fascial transplantation into pleural defects was not attempted, apparently because experimenters believed it would surely fail. Its desirability was especially appreciated by Hirano, who suggested that one sheet of fascia be fixed intrapleurally and a second sheet extrapleurally. In my experiments it was found that a single sheet of fascia, sutured into the defect, afforded permanently firm and air-tight closure. As will be seen from the following experiment, the additional observations at variance with Kornew's findings were: The transplanted fascia loses its characteristic structure relatively soon after operation. Pleural mesothelium grows over the defect, not with the normal arrangement of cells, but in an atypical form characterized by villus-like formations. Very firm adhesions occur between lung and transplant.

Experiment Dog 311. Male, small size. Operation, May 11, 1914. Intratracheal anæsthesia. Curved incision over lateral aspect of left chest. Flap of skin and subcutaneous tissues turned upward. Three ribs exposed near precordium, 5 centimeters of each resected. Underlying pleura removed, making a defect 4½ x 3 centimeters. Sheet of fascia lata, slightly larger, sutured in place; very slight tension. No air leakage. Wound closed in layers. Drainage tube placed in pleural cavity through a stab incision near the base of the thorax, stitched to the skin.[1]

Postoperative course. Uneventful. Drainage tube removed two days after operation. Animal chloroformed October 19, five months after operation. Thoracic wall at site of transplant remained firm and resistant, no suggestion of hernia.

Postmortem examination. Lung firmly adherent to a large part of the area in which fascia had been transplanted. When partly detached, it appeared as if pulmonary pleura alone was adherent. A thin layer of smooth shining tissue, continuous with the parietal pleura spread over the site of the defect, where the lung was not attached. Underneath it there was a firm thin layer of tissue, bright on cross-section, presumably the transplant.

Microscopic examination. Surgical Pathology No. 3153. The transplanted fascia has undergone some hyaline degeneration, stains very faintly and homogeneously in some places, contains many blood-vessels. It merges by insensible gradations with the adjoining connective tissue. Silk sutures mark the regions of transition. The free surface of the transplant is covered by a thin layer of connective tissue and this in turn by the pleural mesothelium. This is complete except where the lung is adherent. At several points the new pleural covering is heaped up into large villus masses attached by narrow pedicles. The lung is adherent to the transplant by a layer of dense connective tissue (pulmonary pleura).

[1] None of the operations involving wide opening of the pleural cavity were successful unless pleural drainage was instituted for a few days.

8. Fascia Transplantation into Defects of the Lung

The only studies made in this field were reported by Hirano. He employed fascia to cover wounds and to reinforce sutures of the lung, and concluded that bleeding, as well as leakage of air from the pulmonary tissues, were controlled by the transplant. Upon investigation one finds that Hirano's work is very incomplete (as he himself notes). Four experiments were performed, the period of postoperative observation varying from one to twelve days. In the latter instance he found that "the pulmonary pleura had grown over the transplant." Concerning the technique of operation, he advised that the fascia be sutured over the defect, the stitch-holes in the transplant not overlying those in the lung (to eliminate leakage of air), and that a slight pneumothorax be induced after operation in order to prevent adhesions to the transplanted fascia.

The experiments I performed demonstrate that fascia sutured *into* a defect of the lung guards amply against air leakage, and affords a firm resistant covering for the gap. Owing to the tendency to the development of empyema in dogs, the postoperative periods were not sufficiently prolonged to determine the ultimate fate of the fascia. In the limited time of observation, however, there was no evidence of an extension of the pulmonary pleura over the transplant. In one instance it was interesting to observe how firmly the fascia held in place despite the presence of an infection.

Experiment Dog 320. Male, medium size. Operation, May 13, 1914. Intratracheal anæsthesia incision in the left seventh intercostal space. Flat defect 1¾ x 1¾ centimeters made on the surface of the lung, replaced by same sized sheet of fascia held in place by interrupted sutures. Leakage of air

from one stitch opening. Stream of air-ether from intratracheal tube discontinued for a few seconds. Lung collapsed. Was permitted to expand slowly; no air-leakage followed. Drainage tube through stab wound at base of chest. Thoracic incision closed.

Postoperative course. Slight temperature. Drainage tube slipped out of pleural cavity 24 hours after operation. Animal appeared in good condition. Wound firmly healed. Death May 27, two weeks after operation.

Postmortem examination. Clear fluid in right pleural cavity, considerable turbid fluid in left cavity. Lungs collapsed, left of rather leathery consistency. Transplant firmly healed in place, could not be dislodged with maximum inflation of lung. Lung and fascia as well covered by a thin fibrinous exudate.

Microscopic examination. Surgical Pathology No. 3047. The lung contains a fair number of blood-vessels near the line of attachment of the transplant. This line is irregular and is made by a thin, dense layer of connective tissue containing many cells. The transplanted fascia is still recognizable as such, but in many places cannot be distinguished from ordinary connective tissue. It contains many round cells and very few polynuclear leucocytes. Its free surface is covered by a faintly staining layer of tissue containing few cells, a fair proportion of which are leucocytes. The union between fascia and lung appears absolutely complete.

No practical use of fascia as a covering for pulmonary defects has as yet been made. The results achieved in experimental work suggest that it may prove of value in operations for the closure of pulmonary fistulæ, or for friable, raw, or bleeding areas of lung encountered at operation. Although not concerned with the question of fascia implantation into lung defects, two suggestions upon the use of fascia in pulmonary surgery, made by Henschen on the basis of experimental studies, are of interest. One was to induce and maintain shrinkage of a lobe of the lung by ensheathing it with a sheet of fascia. The second was a method of air-tight capping of the bronchial stump with fascia.

9. TRANSPLANTATION OF FASCIA INTO PERICARDIAL DEFECTS

The problem of replacement of pericardial defects is encountered in clinical surgery only upon rare occasions. It is then of course essential to restore the continuity of the sac. Suture of the parietal pericardium being impossible or undesirable, plastic procedures are employed to fill the gap. I believed that fascia transplantation offered a much simpler, more rapid, and more efficacious means. This suggestion had already been made by Henschen; he did not, however, attempt to demonstrate its feasibility and it was not taken by up others.

The experiments I performed were not entirely satisfactory, owing to fatal pleural effusions that invariably developed. This well-known tendency to the development of pleural complications whenever the thorax of the dog is opened widely evidently had no relation to the operations on the pericardium.[1] Unfortunately, however, it made impossible the determination of the ultimate effects of the transplantation. The immediate results were excellent, anatomically and functionally, even when large defects were replaced. Firm union between fascia and parietal pericardium took place, despite the little nourishment accessible to the graft and the considerable tension upon it. The inner surface of the transplant became covered by a smooth layer of tissue, free from adhesions. The heart action might possibly have been interfered with in one experiment, that in which an infection in the pericardium resulted in a thin adhesion of the left auricle. These statements are illustrated in the following experiments:

Experiment Dog 325. Small male. Operation, May 18, 1914. Intratracheal anæsthesia. Pericardium exposed through an incision in the left fifth interspace. Circular section 4½ x 2 centimeters removed, phrenic nerve avoided. The defect enlarged rapidly by retraction of the pericardium. Owing to this, some difficulty in suturing sheet of fascia lata 5 x 2½ centimeters into the gap. Pleura drained by a tube inserted through stab wound near base of chest. Intercostal and pericostal suture. Incision in soft parts, and skin, sutured.

Postoperative course. Condition good for six days, then became poor. Dog chloroformed May 26, eight days after operaton.

Postmortem examination. Left lung collapsed, leathery. Considerable purulent fluid in pleura. Fascia firmly fixed in pericardial defect, covered by thin fibrinous exudate. Pericardial lining smooth. No adhesions to internal surface of transplant, which is smooth and bright. Small quantities of clear fluid in pericardial sac.

[1] In most of the experiments requiring wide pleural openings, reported in this paper, fatal pleural effusions developed despite intratracheal anæsthesia and the most careful asepsis.

Microscopic examination. Surgical Pathology No. 3048. The fascia has undergone some degeneration but still retains its typical structure. There is round-cell infiltration about the sutures that joined fascia to pericardium. A small mass of fibrin seals the chink between transplant and pericardium. The latter contains small areas of blood extravasation near the cut margin. The free surface of the transplant is smooth, and is occupied by a thin layer of homogeneous tissue containing few round cells. A similar layer of tissue is spread over the opposite surface of the fascia.

Experiment Dog 355. Large female. Operation, June 22, 1914. Incision in left fourth interspace. Pericardial defect 3 x 3 centimeters replaced by a slightly larger sheet of fascia. Suture of incision in thorax and drainage as in previous experiment.

Postmortem examination. Death ensued eight days after operation. Empyema. Lung collapsed, leathery. External surface of fascia transplant smooth, firm union between it and pericardium. Dry fibrinous exudate in pericardial sac. Thin soft adhesion between the tip of the left auricle and the middle of the transplant.

10. Fascia Transplantation into Defects of the Diaphragm

The first experimental efforts, made by Kirschner, were unsuccessful. In several experiments, carried out by Ikonnikoff and Smirnoff, diaphragmatic defects as large as 3 x 6 centimeters were satisfactorily replaced by fascia. Either omentum or liver was almost always found adherent to the transplant. The outcome of the operation was fatal in a number of instances, apparently because the experimenters approached the diaphragm through abdominal incisions and did not employ any method of inflation of the lungs. Henschen also succeeded in replacing large defects of the diaphragm by fascia. He invariably found the adjacent surface of the lung broadly adherent, and therefore considered this necessary for the provisional nourishment of the graft. Henschen and his predecessors believed that it was highly important to fix the fascial transplant over the defect, either on the thoracic or the abdominal surface, having it sufficiently large to permit generous overlapping at every point. Although histological examinations are not detailed, it appears evident that (1) the functional results were excellent with this technique; (2) adhesions interfered with a satisfactory anatomic result.

If fascia transplantation into diaphragmatic defects is to have any possible clinical application it is essential to demonstrate that the tissue in the gap offers a *lasting* barrier to the development of a diaphragmatic hernia or eventration. This had not as yet been done, and was the chief purpose of the following experiment. Although somewhat altered, histologically, after a period of five months, the large transplant was found firmly united to the diaphragm and sufficiently resistant to prevent any protrusion of the abdominal or thoracic contents. A unique feature was the complete overgrowth of the pleura on the one, and the peritoneum on the other, surface of the transplant, only a thin adhesion of the edge of the liver interfering with a perfect anatomical result.

Experiment Dog 350. Female, medium size. Operation, June 17, 1914. Intratracheal anæsthesia. Long incision in ninth intercostal space, left side. Moist packings isolated diaphragm from lung. Defect in diaphragm 5 x 4 centimeters, involving tendinous as well as muscular portion. Fascia lata of this size sutured in place. Drainage tube through a stab wound at base of pleural cavity. Pericostal and intercostal sutures. Soft parts and skin sutured in layers.

Postoperative course. Uneventful. Drainage tube removed in third day. Chloroform administered November 17, five months after operation.

Postmortem examination. Superior surface of diaphragm exposed by large incision in thorax. Slight adhesion between lung and diaphragm at site of drainage tube incision, but no adhesion to diaphragm in region of transplant. The latter was quite indistinguishable, except as outlined in part by the curved incision that had been made in the muscular portion. The entire upper surface of the diaphragm is smooth and glistening. Water distention of the abdominal cavity elevated the diaphragm as a whole, but did not result in any bulging at the site of the transplant. Except for a thin adhesion of the left border of the liver to the (presumable) situation of the transplant, the abdominal surface of the transplanted area was as smooth and bright as the other. Only when the specimen was removed and held to the light did the position of a number of sutures demonstrate clearly the general outline of the transplant.

Microscopic examination. Surgical Pathology No. 3206. The transplanted fascia shows some degenerative phenomena giving it a hyaline appearance. Its characteristic structure is apparent here and there in the long continuous sheet which

bridges the site of the defect. Many vessels of considerable size (carrying red blood-cells) are found in the fascia, especially near the margin of the defect. Layers of connective tissue overlie the surfaces of the altered fascia and, covering them completely, is a layer of pleura on one side and peritoneum on the other. These layers are continuous with the free surfaces of the normal pleura and peritoneum. Silk sutures mark the transition between the transplant and diaphragm; there is no evidence that either the transplant or the defect has contracted. The absolute union between the fascia and the muscle of the diaphragm is remarkably well demonstrated. Regeneration of the muscle across the defect has not taken place.

Despite the striking experimental results it seems probable that a clinical application of the procedure can be considered only in very rare instances. It has been demonstrated in a number of cases, that large wounds of the diaphragm can be sutured without any great difficulty (by mobilizing the thoracic attachment of the diaphragm, if necessary) and that defects can either be sutured or plugged by neighboring organs; stomach (Albert), liver (Friedrich, Anschuetz), spleen (Sprengel), lung (Borchardt). In other instances pedicled flaps from the thoracic or abdominal wall have been turned into the defect. Nevertheless fascia transplantation appears to offer a much simpler solution of the problem, and, in the future, it may be found desirable especially in the surgical treatment of diaphragmatic hernia or eventration.

II. FASCIA TRANSPLANTATION INTO DEFECTS OF THE LIVER

Excision of tumors and closure of wounds of the liver have been made possible by improved methods of suturing. It has been found, however, that, especially when the tissues are friable, the tendency for these sutures to cut through cannot be eliminated. The newer suture methods have been of little aid in the problem of obliterating large flat defects of the liver. In recent years efforts have been made to replace the tamponade treatment of bleeding raw areas of that organ by fixing living tissues in the defect. The object has been threefold: (1) to permit closure of the abdominal wound; (2) to eliminate the danger of secondary hæmorrhage after removal of the tampon; (3) to obtain the hæmostatic action of living tissue. Various tissues have been employed; fat, omentum, muscle, etc.[1]

It has been demonstrated that muscle transplants become necrotic at an early period. Adipose tissue does not offer good support for sutures and is bulky and irregular. Both experimentally and clinically, fascia has been found to answer best the purposes of any transplant in this field, chiefly because firm tension can be made upon sutures passed through it and the adjacent surface of the liver, and because it covers defects most smoothly.

Various methods of transplanting fascia into wounds of the liver have been described. The adoption of any one of them depends largely on the type of defect encountered. In deliberate excision of portions of the liver, as for tumor, some experimenters (Chessin, Kornew, and Schaak) find it most advisable to place the fascia strips upon the upper and lower surfaces of the liver about the area to be excised, using them as supports for the sutures passed through the substance of the organ. Absolute hæmostasis is obtained by tying these sutures. After removal of the desired section of liver tissue, the sutures are drawn together and the fascia strips are thereby approximated.

Very few clinical reports of fascia transplants into liver defects have been made. A most interesting case was described by Ritter. The patient sustained a rupture of the liver 6 centimeters long, the tear passing entirely through the anterior border. A strip of fascia 4 x 6 centimeters was placed upon the superior, and a similar strip upon the inferior, surface of the organ. Sutures were passed through both strips and the intervening liver tissue, and were drawn tight without evincing any tendency to cut through. The active bleeding ceased promptly; the patient made a smooth recovery. In Henschen's case a strip from the rectus sheath was satisfactorily employed as a simple covering for an incised wound of the liver.

The determination of the ultimate function of fascia transplants into liver defects is evidently of importance, yet this has not been

[1] Many surgeons have investigated this subject: Boljarski, Gluck, Jacquin, Koenig, Loewen, Loewy, McArthur, Senn, Springer, Stucky, Tuffier, Wrede.

even approximately estimated. One month has been the longest period of observation after transplantation (Davis). In this instance the small transplant (3 x 0.6 centimeters) was found viable, and adherent in large part to the underlying liver substance. The following experiment is therefore of interest because it demonstrates that, after a period of 6½ months, the transplant still remains intimately adherent to the original raw area in the liver, a very close fusion having occurred. Although largely disintegrated and replaced by cicatricial tissue, the purpose of the transplant was completely fulfilled. Well-stained liver-cells, individually and in small clusters, were found in the substance of the altered fascia.

Experiment Dog 252. Small male. Operation April 1, 1914. Incision in right hypochondrium. Liver external to the gall-bladder packed off. V-shaped section removed from the free border, measuring about 3 x 3 x 3 centimeters. Considerable oozing. Defect overspread by sheet of fascia 4 x 3 centimeters, folded so that it fit both the superior and inferior surfaces of the liver. It was held in place by a number of interrupted silk sutures. Oozing ceased. Layer suture of the abdominal incision.

Postoperative course. Uneventful. Animal chloroformed October 19, six and a half months after operation.

Postmortem examination. Thin omental adhesion to liver at site of operation and, apparently, to part of the transplant. Surface of the latter slightly rough, but fairly bright and glistening. Absolutely firm attachment of transplant to liver.

Microscopic examination. Surgical Pathology No. 3154. Omentum is adherent to one part of the free surface of the liver by a layer of connective tissue. To the remainder of the surface, the transplanted fascia is intimately adherent. Here also the attachment is by a layer of dense connective tissue. The free surface of the liver is smooth, its cells being adapted here to the surface of the transplant. Of the latter very little that is recognizable remains. For the most part it is transformed into a layer of loosely woven, faintly staining connective tissue. In some parts replacement by areolar tissue is evident. Scattered through the layer of altered fascia are well-stained small islands of liver-cells as well as isolated single or paired cells. The free surface of the transplant is in part smooth, but has a frayed appearance in many places.

12. FASCIA TRANSPLANTATION INTO DEFECTS OF THE SPINAL DURA

More than 80 cases of fascia transplantation into defects of the cerebral dura have been reported, with such uniformly satisfactory results that this application of fascia transplantation can be considered permanently established. Practically all surgeons now employ fascia lata in preference to all the other materials — fat, periosteum, peritoneum, etc.,— when the use of tissue transplants is decided upon. The ideal tissue to replace the dura is of course one possessing an identical structure, strong, and tendon-like consistency and at the same lined with mesothelium. There is, however, no such tissue that can be transplanted autoplastically in sufficient amounts. Fascia transplanted into dural defects in the human being has been examined after varying periods by von Saar, Chiari, Denk, and others. Adhesions between brain and fascia have been found, as well as areas of degeneration in the transplant (Denk's report has already been discussed). Therefore one may conclude that the fascia would be found ultimately converted into scar-like tissue. Functionally, however, the results in the reported cases were almost invariably good. In some instances (as in von Haberer's case) the transplant remained firmly fixed in place despite most unfavorable circumstances. There are a few cases in which the transplant was, with the exception of the skin, the only covering for the brain, and herniæ did not follow. Leakage of cerebrospinal fluid occurred in but two of all the reported cases.

The results of experimental fascia transplantation into defects of the cerebral dura accord with these clinical experiences, in a general way, except that leakage of cerebrospinal fluid has not been described. It is surprising to find that no experimental efforts have been made to determine the results of transplanting fascia into the spinal dura. If the experiments were satisfactory the clinical applicability of the procedure would be evident. The desirability of always closing the dura in operations on the spinal cord is now generally recognized. Conditions arise in which it is found impossible to suture the dura, or in which suture can be accomplished only by compression of the cord. The problem of closing the dura, under such circumstances, has not been solved. The following experi-

ment indicates that fascia can be transplanted into defects of the spinal dura even more satisfactorily than into defects of the cerebral dura, for adhesions to the underlying cord did not develop.

Experiment Dog 91. Male, medium size. Operation, November 1, 1913. Three spines and laminæ removed over lower dorsal region. Dura exposed. Quadrilateral section 3 x 1¼ centimeters removed. Operation on the underlying cord of no interest here. Sheet of fascia from over erector spinæ sutured into defect with usual technique. Layer suture of the wound.

Postoperative course. Uneventful. No leakage of cerebrospinal fluid. Death from distemper December 29, two months after operation.

Postmortem examination. Evidences of distemper in examination of respiratory tract. Wound firmly healed. Muscle intimately adherent to surface of transplant. Inner surface of transplant smooth and free, union between it and adjoining dura evidently complete. Cicatrix in cord, the result of the operation on it, lay directly underneath the transplanted fascia.

Microscopic examination. Surgical Pathology No. 2747. The characteristic structure of the transplanted fascia has largely disappeared, the tissue in the defect being a closely woven connective tissue that has undergone hyaline degeneration. In a few places flat cells are found on the thin homogeneous layer of tissue covering its free surface. A layer of striated muscle is intimately attached to its opposite surface. The fusion between transplant and the adjoining dural tissues is complete, silk strands being the only indication of the line of transition.

A CASE OF FASCIA TRANSPLANTATION INTO A CONGENITAL URETHRAL DEFECT

Large fistulæ of the urethra have been cured by operations consisting in mobilization of the urethra, with or without the addition of plastic flaps taken from the corpora cavernosa. However, failures have followed such procedures and incomplete successes (strictures of the urethra) have also been reported.

Leakage after suture of the urethra is a complication not infrequently observed, and the means taken to prevent it have not proved entirely adequate. The experimental reports of satisfactory reinforcement of suture lines in hollow viscera by fascia grafts, and the successful clinical experiences in the bladder (Koenig, Schmid, Kornew) naturally led to attempts to attach fascia strips over suture lines in the urethra. The results have not been very encouraging. Of four cases described in the literature, only one was an unqualified success. This was a male patient reported by Bachrach, in whom a urethral fistula persisted after incision of a postgonorrhœal abscess. The margin of the defect was freshened, the mucous membrane sutured, and a strip of fascia lata fixed over the suture line. The wound healed by primary union and the patient remained well and free from stricture at the site of operation. In two of the three remaining cases (Kleinschmidt, von Hacker), total failure followed fascia transplantation over urethral suture lines, the fascia becoming necrotic and ultimately expelled, and the fistula recurring in both instances. The fourth case (Hohmeier) may be termed an incomplete success. There was no leakage for eight days after an operation consisting in mobilization of a urethral fistula and suture of fascia over the defect. Upon attempted replacement of the permanent catheter that had been used, the tip of the instrument passed through the field of operation. Leakage of urine and discharge of small fragments of necrotic fascia followed. However, most of the transplant remained in place and the fistula ultimately closed.

At the outset it was stated that suture or plastic flap methods have cured large urethral fistulæ. Considering the discouraging results after transplanting fascia over urethral suture lines, was it justifiable to advocate the replacement of a urethral defect by a fascia transplant? With the experimental experiences, as well as the failures after suture and plastic methods in mind, I believed it fair to attempt this in the case to be reported. Very slight leakage occurred soon after operation and persisted for several days; however, the transplant remained in place and the patient is entirely well a year and a half after operation. It is realized that a single case is no absolute proof of the value of a method. On the other hand, a satisfactory result was obtained despite complications (leakage from one point in the suture line, and separation of the skin resulting in partial exposure of the transplant), and despite the

absence of any attempt to deflect the stream of urine from the field of operation by permanent catheter or suprapubic cystotomy. For these reasons it is hoped that the report of the following case will lead others to attempt the method.

Samuel C., 9 years old, admitted to the Har Moriah Hospital[1] November 26, 1914, with the history of leakage of urine from the under surface of the penis since birth. At the age of three, an operative attempt at cure of the condition failed (details not obtainable). The symptoms persisted as before. At night there is complete incontinence of urine. The patient has occasional good control during the day, but the mother finds him wet very frequently. When voiding voluntarily usually a large part of the urine (approximately one-half) escapes from the floor of the penis, the remainder from the tip. Sometimes most or all of the urine is discharged from the fistula. This happens rarely from the tip of the penis. There is almost always pain on urination.

General examination. The child is pale and poorly nourished. There are no other anomalies.

Local examination. On the under surface of the penis, a short distance behind the glans, there is a slightly depressed orifice about two millimeters in diameter, surrounded by cicatricial skin. The adjacent subcutaneous tissues are firmly infiltrated. A probe enters into the urethra without difficulty. The normal looking urinary meatus admits a good-sized sound that can be passed into the fistula at will, but must hug the dorsal surface to pass into the urethra beyond. Upon several occasions I had an opportunity to witness voluntary urination. Usually the fistula leaked urine in rapid drops at the beginning, the surrounding skin became greatly distended, urine then passed through the fistula in a continuous stream and, a little later, from the meatus in a small stream.

Operation, November 27, 1914. General anæsthesia. An elliptical section of the cicatricial skin about 2 x 1½ centimeters was excised with the short fistulous tract. The defect in the floor of the urethra was then found to involve practically all of its ventral aspect, measuring approximately 1½ centimeters in width and 2 centimeters in length. The edges were freshened. A section of fascia lata slightly larger in size and of the corresponding shape, was removed from the lower part of the thigh and placed in the defect. Its muscle surface was turned toward the lumen. Ten interrupted sutures of very fine cat-gut were passed from the transplant through all the layers of the urethra at the margin of the defect. As a result the fascia was firmly fixed in place, its margin slightly overlapping the margin of the urethral defect. The skin was freed and approximated over the transplant with slight tension. Dry dressing, wound in thigh sutured.

Postoperative course. The patient voided normally for three days. The dressing was then found to be damp and the wound was inspected. The lowest skin suture had separated, and a small area of the transplant was here exposed. Several drops of urine escaped with urination. This persisted for three days. Great care was observed at the necessary changing of dressings.[2] By the time the skin sutures were removed, eight days after operation, the wound was found firmly healed except at the lower angle, where a very small patch of fascia was exposed beneath the slightly separated skin. At that time only one or two drops of urine escaped. Two days later there was no escape of urine, although the skin had not healed over. Nor was there leakage at any subsequent period. The wound healed slowly at the lower angle, the transplant not being completely covered in until two weeks after operation. The patient was discharged entirely well on December 18, 1914, with complete voluntary control of urination.

At an examination about one month after operation, urination was normal, the wound was found firmly healed, a slight infiltration being palpable in the depths. This became more pronounced subsequently, so that at the end of six months a definite plaque was palpable in the scar. In view of the experimental experiences in fascia transplantation into vesical defects the possibility of bone formation in the transplant was considered. Roentgen ray examination[3] was negative, however. The plaque gradually diminished in size and firmness; at the present time (June, 1916) it is imperceptible.

Endoscopy was impossible in this young patient, so that the question of growth of the urethral mucous membrane over the transplant could not be settled. There was never any evidence of stenosis, as tested by sounds upon a number of occasions. When the meatus was shut off during urination the urethral canal was found normally distended at the site of operation. The urinary stream is normal and is projected normally. There has been no interference with erection as observed by the patient's mother upon several occasions. Nocturnal incontinence ceased promptly after operation and has not returned.

[1] Service of Dr. Henry Roth, to whom I am indebted for the privilege of operating upon and reporting this case.

A CASE OF FASCIA TRANSPLANTATION INTO A TRACHEAL DEFECT

Reference has already been made to the one instance in the human being of successful fascia transplantation into a hollow visceral defect — Levit's case of fascia transplantation into a defect of the trachea. He was led to employ this procedure by Hohmeier's

[2] I wish to thank the house surgeon, Dr. Hallerman, for the careful attention he gave to this case.

[3] Kindly made by Dr. Edgar D. Oppenheimer.

experimental studies and because of the disadvantages of the operations that have been employed for tracheal fistulæ.

A small tracheal fistula can be closed by cauterization of the orifice, a method in vogue for many years. Several procedures have been advocated recently[1] for the cure of larger defects. When the fistula is situated near the cricoid cartilage a favorite operation consists in turning down a flap made of the superficial layers of the thyroid cartilage and the adjacent skin, the latter turned inward. The flap is accurately sutured into the defect. Although successful in a number of instances, necrosis of the transplanted cartilage, recurrence of the fistula, and symptoms from protrusion into the trachea have been observed. Furthermore it is a complicated procedure, of limited application, and can result in necrosis of the thyroid cartilage.

Another procedure consists in the construction of an osteocutaneous flap from the sternum (or clavicle) or a similar periosteocutaneous one. The flap is turned upward and sutured into the defect. The scope of this operation is less limited than the former, but it is also less desirable. Recurrence of the fistula and complications in bone healing at the source of the flap have been noted.

To eliminate the disadvantages of flaps, a procedure requiring three stages has been employed. A section of rib cartilage is first implanted under the skin near the fistula. After it has healed in place, a flap of the transplant with overlying skin is fixed in the defect. At the third sitting the flap is detached and its divided pedicle sutured into the remaining part of the defect. Although satisfactory results have been reported, the disadvantages of this procedure are evident.

The drawbacks to these operations having been recognized, several surgeons have practiced circular resection of the trachea for the cure of tracheal defects. Some successful cases have been recorded. The operation, however, is a major procedure (with a possible mortality), depends upon accurate and firm union at every point in the suture line (which may not always obtain in the trachea), and is applicable chiefly to tracheal defects of large transverse diameter.

In one instance the implantation of a sheet of silver filigree has cured a tracheal fistula. This simple procedure may prove to be a solution of the problem, yet the insertion of a foreign body is not comparable with the implantation of living tissue, provided the latter serves the desired purpose. The desired purpose *was* served very simply by Levit, for he replaced the defect with a strong and resistant tissue (the object of the complicated plastic operations) which could ultimately be converted into an equally strong and resistant tissue, and over which the tracheal epithelium could grow without difficulty (a possibility not invited by the plastic procedures or by silver filigree). Levit's case is as follows:

An anterior median tracheal fistula, a short distance from the cricoid cartilage, followed attempted suicide. Three separate efforts to close the fistula by plastic operations failed. Levit operated under local anæsthesia. He removed a section of fascia lata the size of a fifty cent piece (?) (*Silbergulden*) and placed it in saline solution. The margin of the tracheal defect was freshened and the fascia placed over it with the superficial surface facing the lumen. The size of the defect is not stated; the transplant overlapped it by several millimeters. The margin of the fascia was attached to the adjoining trachea by interrupted sutures (catgut?). Some leakage of air and flapping of the transplant were noted, and additional catgut sutures were placed, controlling both. The skin was undermined and sutured over the fascia.

The wound healed by primary union. Cosmetically and functionally the result was excellent. By laryngoscopic examination the site of operation was represented by a flat white circular scar about 10 to 12 millimeters in diameter; the lumen of the trachea was slightly narrowed at this level. The patient was well when seen eight months after operation.

The case I have to report is similar in the findings at operation and in the postoperative course. The technique of operation was somewhat different, the fascia being transplanted into and not over the defect. In consideration of possible leakage with the development of subcutaneous emphysema, one angle of the wound was drained. The transplanted fascia healed in place without reaction, there was no evidence of tracheal stenosis, and the patient remained well.

[1] The literature is to be found in Levit's paper.

Pauline W., age 20, was admitted to the Har Moriah Hospital[1] August 9, 1915, requesting relief chiefly from the cosmetic deformity and difficulty in phonation.

Ten years ago a tracheotomy was performed (for laryngeal diphtheria?). The wound never closed. An attempt to heal it by cauterization failed. The patient coughed almost constantly, but did not complain as much of this as of the above-mentioned symptoms.

The general examination was negative. The voice was husky, made clearer by placing the finger over the fistula. The latter was situated in the midline in the lower part of the neck, at the level of the thyroid isthmus. The hiatus in the cicatricial skin measured approximately one centimeters. There was no evidence of stenosis above the fistula.

Operation, August 17, 1915. Local anæsthesia. The cicatricial tissue and skin about the tracheal opening were excised. The defect in the trachea was freshened and then found to be almost circular, measuring about 2 x 1¾ centimeters. A sheet of fascia lata slightly larger and of the same shape, was removed from the lower thigh and at once transferred into the defect. The muscle surface of the transplant faced the lumen of the trachea. The fascia was fixed to the tracheal wall by four fine catgut sutures, and a continuous suture was made between them (as described in the experimental part of this paper).

There was no leakage or flapping of the transplant with forced breathing. A small rubber-tissue drain was placed down to the transplant. The remainder of the wound was sutured after the skin had been mobilized.

Postoperative course. Uneventful. The drain was extruded on the third day and was not reinserted. Coughing was subdued but almost constant for the first few days, disappeared thereafter and did not return. The wound healed by primary union. In the first few weeks the field of operation bulged slightly with explosive coughing efforts. This ceased subsequently. Direct tracheoscopy was not permitted; by laryngoscopic examination the site of operation was indistinctly seen as a pale, flat, apparently smooth patch.

The patient has remained well (February 1916, six months after operation). Phonation is good, she is free from cough and from any symptoms referable to the transplant. The field of operation is flat, smooth and firm, no infiltration is to be felt.

The fact that the operation of fascia transplantation has been successful in two cases of good-sized tracheal fistulæ does not of course establish it as the one operation for the condition. That it is a much simpler, far less dangerous procedure than those previously employed cannot be questioned. In view of the experimental results that are reported elsewhere in this paper, and of the clinical results experienced by Levit and by myself, I feel no hesitation in urging that fascia transplantation be attempted for tracheal defects before any more complicated operations are essayed. With an experience of one case, it would be presumptuous to argue for the acceptance of my technique rather than Levit's. It may be said that some tracheal stenosis followed Levit's operation, and this was not evident in my case; however, the defect that was replaced appears to have been larger in his patient. It can, however, be definitely stated that, experimentally, fascia transplants have successfully replaced large tracheal defects when sutured into them and have failed to cure such defects when sutured over them.

[1] Service of Dr. A. V. Moschcowitz, to whom I am indebted for the privilege of operating upon and reporting this case.

Summary

The free transplantation of fascia into aseptic fields has a wide sphere of usefulness. It has proved very satisfactory in the replacement of thoracic defects, of aponeurotic defects in operations for various types of hernia, and of defects of the cranial dura. Fascia transplants have been very successfully used, in a variety of ways, for the reinforcement or replacement of ligaments, tendons, and paralyzed muscles. They have proved effective as coverings for wounds of solid organs, especially the liver. Their usefulness has not been clearly demonstrated in other aseptic fields; as sheaths for the isolation of nerves, as strips for occlusion of the pylorus, in fixation or suspension of organs, for separation of joint-surfaces.

There are many advantages of fascia over other tissue transplants (fat, muscle, periosteum, etc.) for the purposes mentioned. Fascia (lata) is most readily accessible, is obtainable in almost unlimited quantities, its removal does no damage. Transplanted fascia has a remarkable tendency to heal in place even under most disadvantageous conditions, requiring minimal nourishment to obviate necrosis. It combines great tensile strength with slight tendency to stretch or to contract. It is most readily adaptable to

the shape of any organ and, technically, can be most easily handled. Finally, fascia can be invariably transplanted autoplastically. The other transplantable tissues have some of these characteristics, none of them has all. The ultimate fate of transplanted fascia has not been definitely determined. The experiments I have reported indicate early disintegration in non-aseptic fields, degeneration at later periods in aseptic fields. Of practical importance is the fact that the resultant firm connective tissue is as serviceable as the original transplant.

These striking qualities led to attempts to employ fascia transplants in non-aseptic fields: in the presence of infection, or about hollow viscera. A few successes and about an equal number of failures followed. The use of fascia for such purposes was deemed undesirable, the successful results having been considered fortunate accidents.

Experimentally, fascia transplants have been found satisfactory for the reinforcement of suture-lines in hollow viscera. They were successfully employed in a few instances to bridge small tracheal fistulæ, and they occasionally prevented leakage from small œsophageal and bladder fistulæ. These occasional satisfactory results were found to depend upon healing by contraction of the defect. For this reason failure followed every experimental effort to replace appreciable œsophageal and vesical defects.

The technique employed in these experiments on hollow viscera (and on other organs) was the attachment of the transplant over the defect. To offer any chances for uniform success a method was evidently required to prevent the cut margin of the organ from rolling back, to give sutures a firmer hold on the organ by passing them through all its layers, to more readily supply the graft with provisional nourishment, and to invite the overgrowth of the lining mucous membrane of the organ. It is demonstrated in this paper that these requirements were met satisfactorily by suturing fascial sheets into instead of over defects of hollow viscera (and of other organs). With this technique I obtained the following results:

1. Large vesical defects (up to about one-half the bladder-wall) were replaced by fascia with uniform success. The functional and anatomic results were excellent. They were attained by the upbuilding of a new bladder-wall. Epithelial overgrowth at the site of the defect was complete at an early stage. The newly formed bladder-wall was as thick as or thicker than the remainder, and equally or more resistant to pressure from within. This was probably due in part to the fact that bone appeared invariably at the site of the defect, definitely limited to that area. The osseous tissues appeared remarkably soon after operation, reaching the height of their development in the second or third month. In conjunction with the bone there was formed typical bone-marrow (and cartilage, in one experiment) and an ensheathing, periosteum-like layer of connective tissue. That the transplanted fascia as such was not responsible for the formation of bone, was demonstrated by the development of osseous tissue when fat was used to bridge vesical defects. The formation of bone and related tissues was explained by the theory of connective-tissue metaplasia, the assumption being that calcium salts, derived from the urine, were the centers of stimulation.

Another uniform feature was the presence of smooth muscle in the connective tissue occupying the defect. It was continuous with the muscle of the bladder-wall. Its presence was accounted for on the basis of smooth muscle regeneration.

2. The immediate anatomic and functional results of replacement of extensive ureteral defects by tubes of fascia were satisfactory. Ultimate results could not be ascertained, for reasons that have been stated.

3. Large tracheal defects (involving as much as three cartilage rings and most of the anterior aspect of the organ) were invariably replaced successfully. The anatomic result was ideal, ciliated tracheal epithelium growing completely over the transplant soon after operation. The functional results were satisfactory, the newly formed tracheal wall being rigid and resistant, the narrowing of the tracheal lumen being insignificant.

4. Large œsophageal defects were replaced successfully in all experiments. Slight steno-

sis developed soon after transplantation; at later stages this was almost imperceptible. Epithelial overgrowth was complete. The functional was as good as the anatomic result.

5. Perforation through the transplant invariably followed its simple implantation into gastric defects. On the other hand, smooth healing always occurred, even with very large defects, when gastro-enterostomy, with or without pyloric exclusion, was added. This striking contrast demonstrates the profound influence of gastro-enterostomy upon healing of gastric lesions near the pylorus. Healing was firm and complete, gastric mucous membrane completely overgrowing the site of the defect. In one instance bone formation in the scar tissue was observed. Its development was explained on a basis similar to that suggested in the group of bladder experiments.

6. Fascia transplantation into small defects in the upper part of the small intestine was occasionally successful, succeeded more often in the lower part of the small intestine, was most successful in the large intestine. In the latter, larger defects could often be satisfactorily replaced. Healing took place by the upbuilding of new tissue and partial epithelial overgrowth, as well as by some contraction of the defect.

The following results were obtained in transplanting fascia into defects of organs other than the hollow viscera:

1. The (altered) transplant became firmly and permanently adherent to large defects made in the liver. Previous experiments had only demonstrated good immediate results, whereas, for stated reasons, the determination of the more distant outcome was considered of importance.

2. Large defects of the diaphragm were satisfactorily replaced by fascia. The (altered) transplant healed firmly in place, permanently preventing the development of hernia or eventration. Its surfaces were completely overgrown by parietal pleura and peritoneum respectively. Previous experiments had not demonstrated this mesothelial overgrowth. They dealt with immediate results, which were good functionally, indifferent anatomically.

3. Large pleural defects were satisfactorily replaced by fascia. The final results were good, anatomically and functionally. Overgrowth of pleural mesothelium was complete except where the lung was adherent. Adhesions were not encountered in some previously reported experiments.

4. Good immediate results were obtained in transplanting fascia over large defects of the lung. The firm union prevented leakage of air; the free surface of the transplant was smooth and non-adherent. Final results could not be ascertained, owing to the development of pleural effusions.

5. The immediate functional and anatomic results of transplanting fascia into large defects of the pericardium were good. Final results could not be ascertained, owing to the development of pleural effusions.

6. Large defects of the spinal dura were satisfactorily replaced by fascia. Adhesions between the incised underlying cord and the (altered) transplant did not develop. Previous experiments and operations dealt with defects of the cranial dura; adhesions between the transplant and the unoperated brain were encountered.

The clinical aspects are discussed in each of these groups of experiments. In addition, two clinical reports on fascia transplantation into defects of hollow viscera are appended. In one it is demonstrated for the first time that a large urethral defect can be very satisfactorily and very simply replaced by fascia. A similar demonstration is made in a large tracheal defect; this is the second case recorded in which fascia has been transplanted into a tracheal defect.

It is a pleasant duty to close with an expression of my indebtedness to Dr. William C. Clarke, Director of the Laboratory of Surgical Pathology, for many invaluable suggestions and constant co-operation in the progress of this work.

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THE USE OF SMALL BONE TRANSPLANTS IN BRIDGING A BONE DEFECT

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In certain types of fractures of one of the bones of the forearm where there is malunion with loss of substance it is frequently difficult to properly brace the resulting defect. The bone is too small to maintain a transplant in position by the use of a Lane plate or other device; and the insertion of an intramedullary splint with a dowel is a procedure of considerable difficulty and requires a large exposure of the fractured bone. In performing bone transplant operations in dogs while pursuing the study of bone repair the writer was struck with the universally good results obtained by transplanting small bone fragments, 1–2 mm. in size, to fill a defect in the shaft of the radius. Although this study is purely an experimental one, it is reasonable to assume from the results obtained that it will be of distinct clinical value in well selected cases.

Description of a Typical Animal Experiment.—Under ether anæsthesia the radius is exposed for a distance of at least 4 cm., the surrounding structures are dissected free from the shaft and a portion of the shaft about 3 cm. long is removed. The periosteum is excised for a distance of 1–2 cm. from both cut ends of the radius. The excised piece is now freed of its periosteum, it is split lengthwise and all visible endosteum is removed. Following this it is cut into small fragments 1–2 mm. in size, and these little fragments are inserted into the bone defect (see Fig. 1). The muscle, fascia, and skin are closed in layers; a gauze dressing followed by a plaster-of-Paris bandage is applied.

At regular intervals following operation radiographs have been taken and the dogs sacrificed. The leg is then examined clinically and later decalcified and sections are made for microscopic examination.

Results.—Twenty-six dogs have been operated upon in the manner described above, of these two have become infected, two fractured the radius by jumping off elevations and angular union occurred. Of the remaining twenty-two good union has occurred in almost every case. This is remarkable, as it is impossible to immobilize the foreleg satisfactorily and the dogs use them from the very first day post-operative. The gross examination in the early stage reveals numerous irregularities of the bone; as time progresses, however, the rough areas are absorbed and the bone resumes its normal form. It is interesting to note that whenever a tendon is in close proximity to these fragments it eventually forms a depression such as normally occurs in the bicipital groove. In specimens one year after operation it is often difficult to find the location of the transplants.

Radiographic Findings.—In studying a series at intervals after operation it is seen that the transplants become gradually smaller while about them a formation of new bone occurs. At later stages the form and contour of the shaft is re-established. In two

instances where there has been clinical union a transverse line has been observed by X-ray (Figs. 12, 13, 14 and 15).

Microscopical sections taken from seven days to one and one-half years show that there are two main factors involved in the repair of these bone defects: Namely, first, the bone fragments, second, the organization of connective tissue about the fragments. Let us consider these two factors separately.

1. *The Transplanted Bone Fragments.*—In from ten to twenty days after operation the bone cells in the central portions of the fragments lose their standing reaction, while those at the periphery are still viable.

Immediately following transplantation clotted blood is seen in the Haversian canals with fibrin formation. In about four weeks blood-vessels containing normal appearing blood-cells are seen. It is difficult to determine whether the blood is re-established through the old vessels or new ones are formed. About these larger canals there appear two or three concentric layers of bone cells with normal staining nuclei. At the periphery of the fragments areas of rarefaction and areas of new bone formation occur (Fig. 7).

2. *The Connective Tissue About the Fragments.*—After the operation blood clot forms about the fragments, gluing them together; it becomes organized by granulation tissue; fibroblasts are seen growing in from the periphery and then young blood-vessels appear. As the granulation tissue becomes organized calcium salts are deposited in the perivascular areas forming a very definite new bone. A very low power microscopical picture of this connective tissue at this stage appears similar in design to an irregular lace curtain pattern, the dark staining areas which correspond to the web of the curtain consist of new bone, while the light staining areas are composed of blood-vessels and young connective tissue (Figs. 9 and 10).

At a later period these new bone areas increase in size at the expense of the young connective tissue, the latter gradually changing into fibrous connective tissue. Sections under high power show gradual graduations of the cellular elements; from connective tissue to bone, from connective tissue to fibrocartilage, and from fibrocartilage to bone.

As time progresses the bone fragments are gradually absorbed and lose their identity in the mass of new bone forming from connective tissue. In a year the medullary canal has been re-established and we have tubular bone which is difficult to distinguish from the normal shaft. The Haversian canals have reformed in the direction of the long axis of the shaft. The bone is covered with a connective tissue layer resembling periosteum (Fig. 5).

In the two or three cases where the X-ray showed an artificial joint we find that the adjacent bone surfaces are covered with cartilage and an adventitious joint has been formed (Fig. 4).

Too much importance has been placed by most authors upon the origin of the bone cell as the vital factor in bone repair. This has clouded our conception of the process. Bone is mesoblastic in origin, and in its repair we find that calcium salts are deposited on the intracellular elements of connec-

FIG. 1.—Showing how radial transplants have fused. *cc*, bone defect filled with transplants. *a*, duration, 332 days; *b*, duration, 163 days; *c*, duration, 271 days.

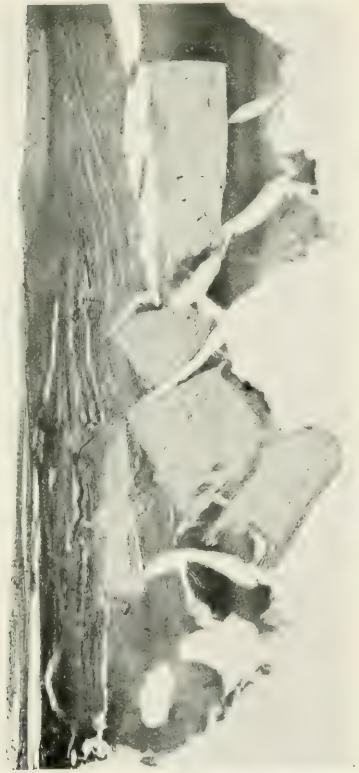

FIG. 2.—Duration, 4 days. Appearance of fragments soon after transplantation. They are surrounded by blood-clot.

FIG. 3.—Longitudinal microscopical section (low power). Duration, 40 days. *a*, ulna; *b*, radius; *cc*, fragments in radial defect. Rarefaction of fragments with new bone formation about them.

FIG. 4.—Longitudinal microscopical section of radius and ulna. Duration, 141 days. *a*, ulna; *b*, radius; *cc*, cut ends of radius with bone fragments between; *d*, cartilage forming false joint; *e*, bone fragment—nuclei do not stain—areas of rarefaction seen near periphery; *f*, fibrous tissue capsule continuous with periosteum; *g*, new bone formation about periphery of fragments.

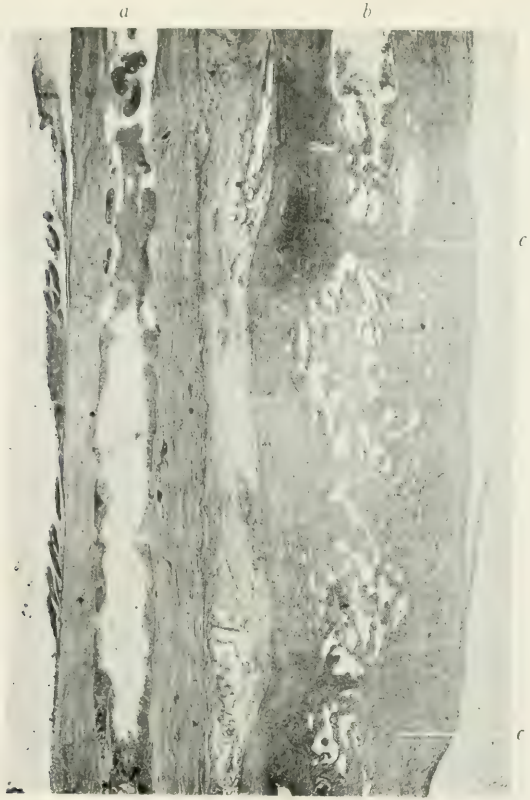

FIG. 5.—Longitudinal section. Duration, 347 days. *a*, ulna; *b*, radius; *cc*, boundaries of transplanted fragments. Medullary cavity is being reformed. Tendency of Haversian canals to run in long axis of shaft.

FIG. 6.—Duration, 370 days. Good union; fragments have disappeared. *aa*, area of transplants.

FIG. 7.—High power of portion of transplanted fragment. *a*, fragment—nuclei of bone cells do not stain; *b*, new bone formation about the periphery of the fragment—nuclei show normal stains; *c*, blood-vessels in Haversian canals—blood-cells show normal staining reaction—two or three layers of normal appearing bone-cells about blood-vessels.

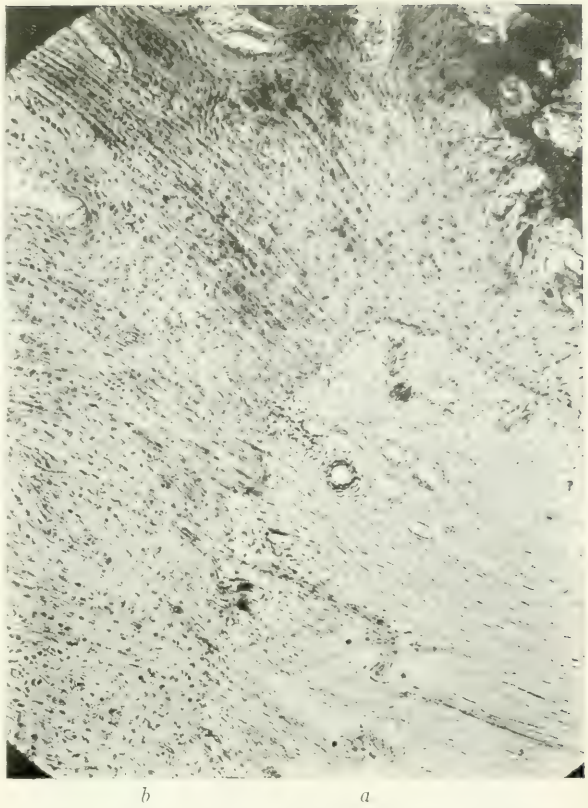

FIG. 8.—High power, showing junction of connective tissue and bone. Collagen fibres seen extending into the bone. Cells are of same character in bone and connective tissue, but the chemistry of the intercellular substance has changed. *a*, connective tissue; *b*, bone.

FIG. 9.—High power view of new bone formation. Duration, 12 days. *a*, granulation tissue; *b*, blood-vessels; *c*, new bone—the gradations of the intercellular substance can be plainly seen; there is no specific bone-cell, but a gradation of connective-tissue cell with calcium deposited as bone about it.

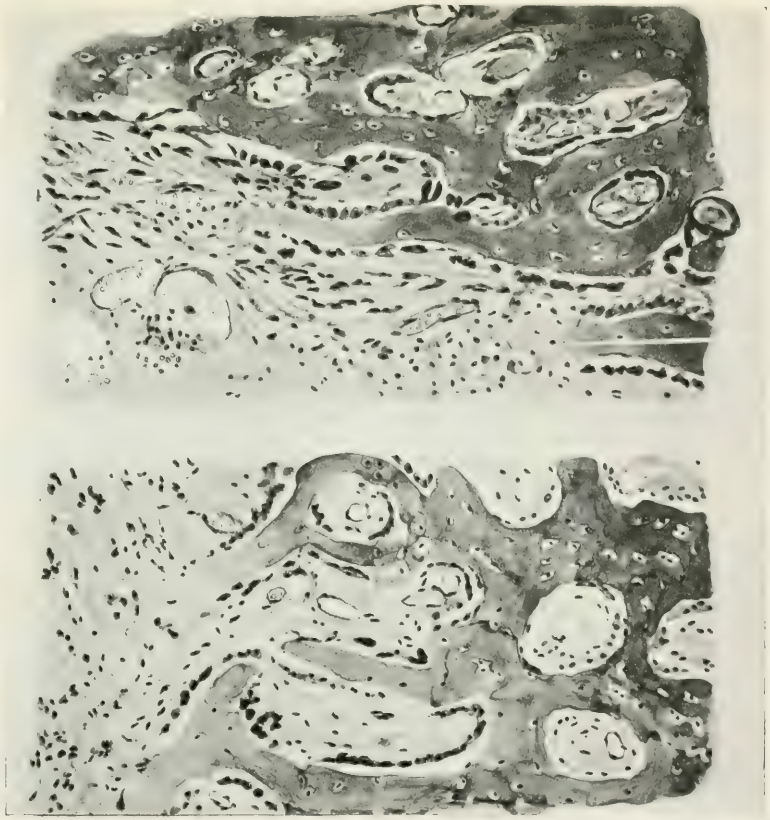

FIG. 10.—High power of bone of involucrum in case of osteomyelitis. Duration, 2 months. At *a* may be seen the gradual fading off of the bone matrix into the collagen fibres. The gradual transformation of a fibroblast to a bone-cell is seen. (Courtesy of Dr. William Clarke.)

FIG. 11.—High power of fracture of humerus. Duration, 11 days. Transformation of connective tissue into cartilage. (Courtesy of Dr. Allen O. Whipple.)

FIG. 12.—X-ray shows bone fragments filling defect. Duration, 13 days.

FIG. 13.—X-ray shows bone hypertrophy with union of fragments. Duration, 141 days.

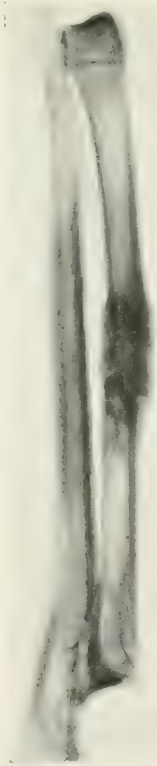

FIG. 14.—Duration, 134 days. Fragments have united —no cross union between radius and ulna.

FIG. 15.—Duration, 370 days. Contour of bone is approaching the normal; individual fragments no longer detected by X-ray.

tive tissue forming new bone. The connective tissue cell then, by a process of metaplasia, becomes a bone cell. Periosteum is a connective tissue and hence is prone to form bone, but it is not the only connective tissue that has this function. If this theory is assumed, it will explain the extra-skeleton formation of bone as in arteries, myositis ossificans, ovaries, kidneys, etc. (Figs. 9, 10, and 11).

Neuhof, working in the experimental Research Laboratory of Columbia, found bone constantly present in fascia lata and fat transplants in the bladder and occasionally in the stomach.

In the operative treatment of comminuted depressed fractures of the skull surgeons have been accustomed to leave the fragments in place, the fragments unite and prevent the brain hernias that occurred before this procedure was adopted. Finney, at Johns Hopkins, has used this method in ununited fractures of long bones.

In the experiments described above the periosteum was removed from the fragments in order to observe if such fragments would live; clinically it would seem advisable to leave the periosteum attached, as it is plausible to assume that the blood supply will be more quickly supplied to the fragments through the medium of the periosteum.

From the clinical point of view this procedure offers an adequate method of bridging a bone defect if there is another bone present to act as a splint and if it is possible to hold the bones in adequate position by external support. It offers the advantage of not having to expose a very large area and of not having to introduce a foreign body.

No originality is claimed for this method, as bone fragments have often been used to fill bone cavities. McEwen, in his work, reports bone growth from bone fragments.

I wish to express my thanks to Dr. William C. Clarke, of Columbia University, for invaluable advice and for the privilege of performing these experiments in the Surgical Research Laboratory of Columbia University.

[*Reprint from Interstate Medical Journal, Vol. XXIV, No. 8, 1917.*]

AN EXPERIMENTAL STUDY OF THE EFFECT OF SUNLIGHT UPON REPAIR OF FRACTURES.*

By HAROLD NEUHOF, M. D., New York City.

Sunlight has been invoked for the treatment of a great variety of conditions, and reports of its efficacy have appeared, from time to time, throughout the history of medicine. It remained for Rollier to differentiate clearly between the beneficial influence of fresh air and the effect of sunlight. He placed heliotherapy upon a well-defined basis in its application to one condition: surgical tuberculosis. His successes over a period of many years have been so remarkable that to heliotherapy must be ascribed the best results that have as yet been obtained in the treatment of surgical tuberculosis.

Many studies have demonstrated that sunlight has an undoubted effect upon the body tissues, chiefly by its violet and ultraviolet rays, but our knowledge of the nature of that effect remains obscure. In view of their results, it is not surprising to find that Rollier and his associates believe that the sun's rays have a well-nigh specific healing effect upon tuberculous lesions. Briefly, their plan of treatment consists in exposing successively all parts of the body to sunlight, the dosage being progressively increased until exposure of the entire body is practised. The exposure of the tuberculous focus itself is of *secondary or no importance* in the result, the healing effect of the sun's rays being a general one on the body tissues. It would lead too far afield to discuss the many important details of the application of heliotherapy. Two conclusions derived from Rollier's work are germane to my subject. First: Upon analysis of his case-reports the most brilliant results are to be found among the patients suffering from bone and joint tuberculosis. Secondly: Although heliotherapy for months or years is necessary in order to obtain good and permanent results, Rollier often noted improvement soon after the treatment was instituted.

From a consideration of the foregoing, there arose several questions that appeared susceptible of experimental proof. 1. Has sunlight, by its general action upon the body tissues a demonstrable healing effect upon non-tuberculous lesions? 2. If so, could that effect be observed at an early stage, that is, within several days or weeks? 3. If it existed would such acceleration of repair be especially notable in bone lesions?

*From the Department of Surgery, College of Physicians and Surgeons, Columbia University.

The experimental work consisted in the study of the repair of fractures[1] in rabbits exposed to sunlight. Three series of experiments were performed at different seasons of the year—spring, summer, and autumn. Animals of approximately the same age and weight were chosen for each set. The identical fracture having been made in all of one series, the rabbits were separated into two groups: One-half for the sunlight, the other, away from the sunlight. All were placed on the roof, receiving the same food and at-

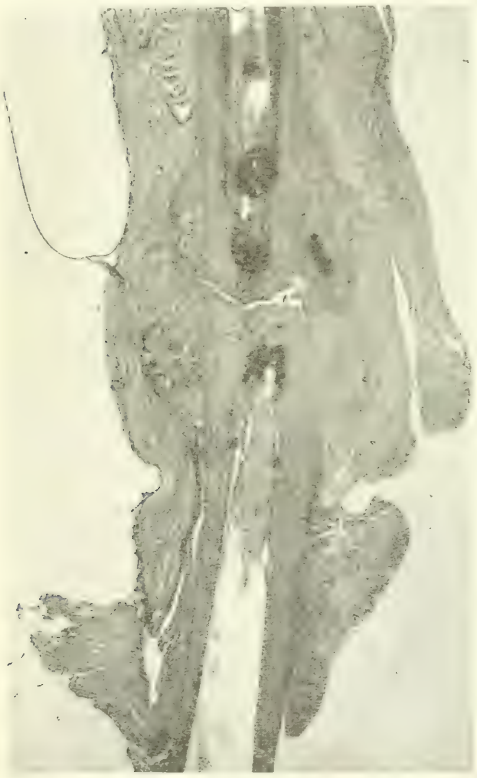

Fig. 1.—Rabbit No. 3458. No sunlight. Barely palpable callus. Very soft union.

Fig. 2.—Rabbit No. 3457. Sunlight. Largest callus of this group of experiments. Soft union.

tention. The only difference was that the members of one group were exposed daily to the sunlight, the others were screened from the sun. The screening was arranged to avoid any interference with air supply. The same large cage space was given to all. The sexes were segregated. Whenever there was any doubt as to physi-

[1]The underlying practical reason for choosing fractures for investigation was my belief that the treatment of fractures, in contrast with the treatment of extensive wounds elsewhere in the body, has been too purely local and mechanical in character. Postive experimental evidence might lead to the assumption of a broader viewpoint. It might, for example, suggest a means for accelerating healing of fractures or for avoidance of non-union when the common causes therefor (constitutional disease, interposition of soft parts, etc.) do not exist.

cal condition the rabbits that appeared best nourished were always selected for controls.

The bones chosen for fracturing were those in which there would be minimal motion after operation—ribs and fibulae. By this choice any great variation in the mobility of fragments after operation on various bones—a factor that might invalidate the results —was avoided. The ribs were thought especially desirable for experimentation for, if two were divided, considerable separation would result, and the manner of healing at the cut ends could be

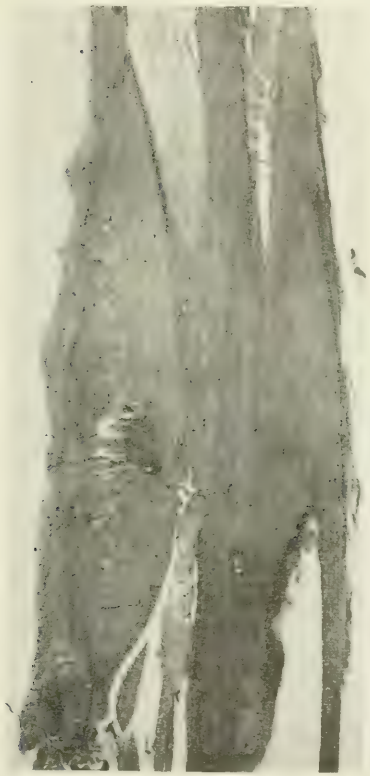

Fig. 3.—Rabbit No. 3459. No sunlight. Somewhat larger callus than No. 3458. Soft union.

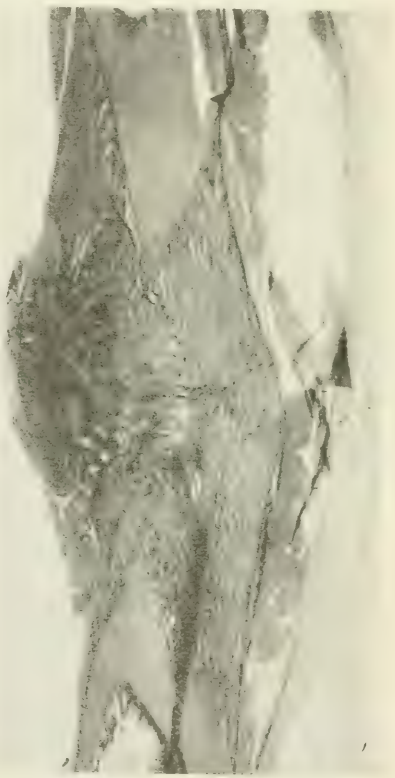

Fig. 4.—Rabbit No. 3460. Sunlight. Large callus, but smaller than No. 3457. Almost solid union.

best studied. The technic of operation was very simple. Under full ether anesthesia and with adequate asepsis, a short incision was made over the bone. Bleeding from the soft parts was carefully controlled. Without any handling of the periosteum the shaft of the bone could be sufficiently exposed for section. Together with its undisturbed periosteum the bone was divided transversely by a single cut of a sharp heavy scissors. The soft parts and skin were carefully sutured in layers. Twenty-four experiments were per-

formed. Reports will be limited to those in which primary union occurred and the animals were in excellent condition and not pregnant at the conclusion of the experiments.[2] Changes in weight were insignificant; in most instances there was a slight increase. No difference either in weight or in general condition was discernible between the "sunlight" and the "no sunlight" rabbits. There was no recognizable difference in the healing of the incised soft parts. Therefore, my observations will be confined to the question of bone repair.

Differences in the repair of the fractures were estimated in sev-

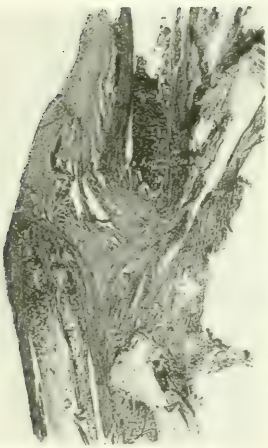

Fig. 5.—Rabbit No. 3226. No sunlight. Very small callus. No union.

Fig. 6.—Rabbit No. 3230. Sunlight. Very large callus. Good union.

eral ways: X-ray examination, tests of the strength of union, inspection of the gross specimens, and microscopic examination. By all these means, but especially by the last, definite differences were observed. In almost every instance fracture-healing in the "sunlight" rabbits was far more active and vigorous than in the "no sunlight" animals. X-ray examinations showed greater broadening and tufting of the fractured ends, and earlier and more active callus formation. The radiographic evidence was supported by inspection

[2]The differences in repair to be noted between the sunlight and no sunlight experiments were paralleled in the animals whose general condition became poor or whose wounds were infected. The latter are excluded from consideration because conclusions can manifestly not be drawn from them.

of the isolated specimens; this disclosed greater thickening at the site of fracture in the "sunlight" rabbits. Strength of union was tested by fixing the ends of the isolated bones (cut into equal lengths) and suspending weights at the site of fracture.[3] Specimens from the "sunlight" animals almost invariably withstood more weight before bending than those from the controls.

As has been stated, however, the most striking differences were observed in the microscopic examination. In the specimens from the "sunlight" animals there was almost invariably a much broader and more vascular zone of activity at the fracture ends, and earlier and more vigorous osteogenesis between the two fragments. Many slides were made from each specimen. The contrast was very marked in about 75 percent of the slides, less marked in the remainder. In not a single instance was there greater activity of repair in the control. In short, the controls demonstrated normal repair as ordinarily seen after experimental fracture; the "sunlight" animals presented hyperactivity of repair.

PROTOCOLS OF EXPERIMENTS.

Spring Experiments on Fractured Fibulae—Operations performed on April 13, 1915. Experiments terminated at the end of eleven days. Of these seven were very sunny, the remainder cloudy and sunny; rain on one day. *Results*:

Rabbit No. 3458. No sunlight (Fig. 1). Barely palpable callus. Very soft union.

Rabbit No. 3457. Sunlight (Fig. 2). Largest callus of this group of experiments. Soft union. Bone cracked on removing specimen.

Rabbit No. 3459. No sunlight (Fig. 3). Somewhat larger callus than 3458. Soft union.

Rabbit No. 3460. Sunlight (Fig. 4). Large callus, but smaller than No. 3457. Almost solid union.

Autumn Experiments on Fractured Ribs—Either the sixth and seventh or the seventh and eighth ribs were divided in each experiment. Operations performed on October 13, 1916, terminated at the end of seven weeks with a single exception (rabbit No. 3225). About 75 percent of the days were sunny. *Results*:

Rabbit No. 3226. No sunlight (Figs. 5 and 7). Very small callus in each rib. No union in either.

Rabbit No. 3230. Sunlight (Figs. 6 and 8). Very large callus in each rib. Good union in one, no union in the other.

Rabbit No. 3225. No sunlight (Figs. 9 and 11). Experiment terminated after *ten* weeks. Moderate callus in each rib. Good union in one rib; very soft union despite unusually good apposition of the rib ends, in the other.

Rabbit No. 3228. Sunlight (Figs. 10 and 12). Good union and large callus in one rib, soft union and moderate callus in the other.

Rabbit No. 3227. No sunlight (Fig. 13). Small callus and no union in one rib, soft union with moderate callus in the other.

Rabbit No. 3229. Sunlight (Fig. 14). Good union in both ribs. Large callus is one, of moderate size in the other.

Summer Experiments on Fractured Fibulae—Operations on July 16, 1915,

[3]This test was not employed in many of the experiments because it was thought that the microscopic picture might be distorted thereby.

experiments terminated at the end of three months. Considerable rainy and cloudy weather. The contrast between the sunlight and no sunlight experiments, as determined by microscopic examinations, was not nearly so definite as those noted in the short-time experiments, and will therefore not be illus-

Fig. 7.—Rabbit No. 3226. No sunlight. Very small callus. No union.

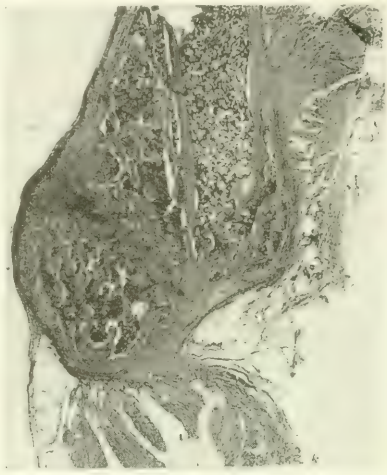

Fig. 8.—Rabbit No. 3230. Sunlight. Very large callus. No union.

Fig. 9.—Rabbit No. 3225. No sunlight. Moderate callus. Good union.

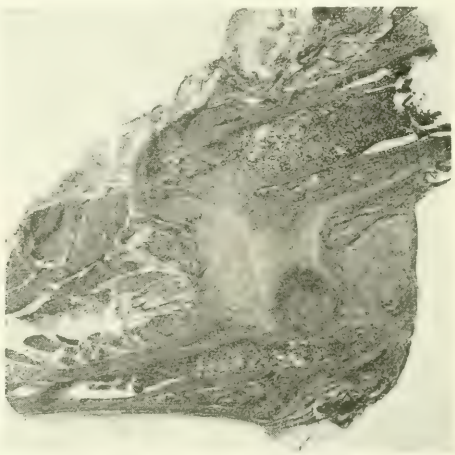

Fig. 10.—Rabbit No. 3228. Sunlight. Large callus. Good union.

trated by microphotographs. Difference in the size and density of the callus in the two groups of experiments was fairly well seen in the roentgenograms. Results of inspection and palpation of specimens:

No. 3669. Sunlight. Firm union. Easily visible, solid callus.
No. 3669. Sunlight. Firm union. Solid callus of moderate size.

No. 3670. Sunlight. Firm union. Small callus, readily felt.
No. 3671. No sunlight. Firm union,. Callus barely visible, not palpable.
No. 3672. No sunlight. Fibrous union. Small callus.
No. 3673. No sunlight. Firm union. Callus not seen or felt.

For purposes of comparison the microphotographs are arranged with the "no sunlight" specimens on the left, the "sunlight" speci-

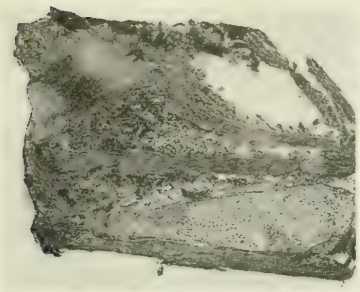

Fig. 11.—Rabbit No. 3225. No sunlight. Moderate callus. Soft union.

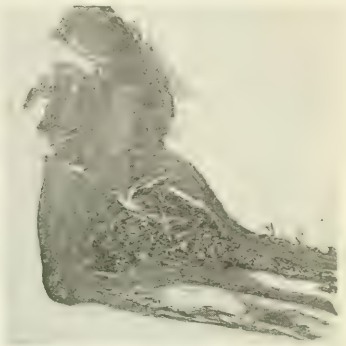

Fig. 12.—Rabbit No. 3228. Sunlight. Moderate callus. Soft union.

Fig. 13.—Rabbit No. 3227. No sunlight. Small callus.

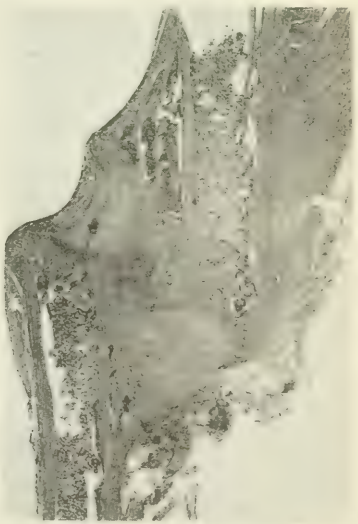

Fig. 14.—Rabbit No. 3229. Sunlight. Good union. Large callus.

mens on the right side. Sections were paired in which there was, as far as could be obtained, similar arrangements of the bone ends. Owing to the different planes often occupied by the rib ends it was occasionally impossible to get enough of both in the section to give a good picture; in such instances a characteristic picture of one rib end is shown.

CONCLUSIONS.

1. Sunlight has a demonstrable reparative effect upon fractures due to an ill-understood action on body tissues. With the demonstration of this phenomenon the healing influence of the sun's rays cannot be deemed peculiar to surgical tuberculosis alone.

2. The evidence of the action of sunlight is found in an acceleration of repair at the fractured ends of bones and an increase in the reparative zone.

3. This evidence is observable as early as after eleven days' exposure to the sun's rays.

4. In contrast to the unrecognizable effect upon healing of the soft parts in these experiments the influence of sunlight upon the bone lesions is especially conspicuous.

5. The practical significance of the experiments lies in the demonstration of this notable influence of sunlight upon bone repair and especially in the demonstration that it can be promptly obtained.

6. The reparative action of sunlight depending on its violet *and ultraviolet* rays, and sunlight not always being obtainable or applicable, the question of the use of ultraviolet light in the treatment of fractures deserves clinical investigation.

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DRAINAGE IN APPENDICITIS *

A REVIEW OF CASES OF ACUTE APPENDICITIS REQUIRING DRAINAGE AT THE PRESBYTERIAN HOSPITAL, NEW YORK, N. Y., 1915-1918

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FROM January 1, 1915, to December 1, 1918, 622 cases of acute appendicitis were admitted to the Presbyterian Hospital, New York City. This number includes cases in which the inflammatory process was fairly limited to the appendix itself, and recorded as acute appendicitis; and cases in which the peritoneal cavity presented evidence of varying degrees of contamination or infection from organisms passing through the appendix wall. The latter have been somewhat arbitrarily, but for the most part satisfactorily classified as follows:

1. Acute appendicitis with acute local peritonitis.
2. Acute appendicitis with peritoneal abscess, subcæcal, mesiocæcal, laterocæcal, etc.
3. Acute appendicitis with extraperitoneal abscess, retrocolic or retrocæcal.
4. Acute appendicitis with acute diffuse peritonitis.
5. Acute appendicitis with progressive fibrino-purulent peritonitis.

Definition of diagnostic terms:

1. *Acute Appendicitis.*—The pathological changes are limited to the appendix, meso-appendix, and in some cases the cæcal wall in the immediate

* NOTE: As a result of the experimental study of certain chlorine antiseptics in localized peritoneal infections in dogs,[1] the antiseptic post-operative treatment of cases of acute appendicitis requiring drainage was undertaken first in February, 1918, as a routine in the wards of the Surgical Service at the Presbyterian Hospital, New York City. Aside from the eighteen cases which have been treated by the writer, the method has been employed by others in thirteen cases of appendicitis and in a number of intra-abdominal drainage tracts accompanying other conditions.[2] That a fair criterion might be established by which judgment could be passed upon the results attained by the antiseptic method, an analysis of 263 similar cases occurring during the past four years has been made. This period corresponds with that of the follow-up system of the hospital, and is, therefore, especially satisfactory in determining the incidence of certain sequelæ and late secondary procedures.

[1] A Study of the Intra-abdominal Use of Dakin's Fluid and Dichloramine-T Solutions, with Special Reference to Local Peritoneal Infections. *Jour. Exp. Med.*

[2] The Clinical Application of the Carrel-Dakin Method to Cases of Acute Appendicitis Requiring Drainage. *Surg., Gynec. and Obst.*

vicinity of the base of the appendix. The serosa of the appendix must show acute inflammatory change, *i.e.*, redness. Fibrin deposit usually is present in some degree. Gangrenous areas of the wall or extensive gangrene of the appendix may exist. A very recent perforation may be present. Free peritoneal exudate, clear, cloudy, odorless or with faint odor may be found.

2. *Acute Appendicitis with Acute Local Peritonitis.*—Lesions of the appendix present are those of acute appendicitis with a larger percentage showing gangrene and perforation of the wall. Acute inflammatory changes are present in the coils of intestine adjacent to the appendix; *i.e.*, redness, changes in lustre, and in many instances fibrinous deposits; omentum shows various stages of involvement. Exudate is present as in the former condition, or there may be a definite odor to the pus without localization. The latter often indicates a transitional stage between acute local peritonitis and peritoneal abscess.

3. *Acute Appendicitis with Peritoneal Abscess.*—The appendix usually presents signs of advanced inflammatory changes. One or more localized collections of definite pus must be present. In most instances this is foul smelling, but may be odorless. The pocket of pus may be walled off by organized adhesions, but often minimal delicate adhesions of fibrin alone are found. Outlying localized or diffuse peritonitis with free exudate may occur, and in such cases the additional diagnosis is given and cross-referenced.

4. *Acute Appendicitis with Extraperitoneal Abscess.*—Includes cases in which the abscess from the appendix originates in tissues without the general peritoneal cavity and involves the extraperitoneal areolar connective tissues.

5. *Acute Appendicitis with Acute Diffuse Peritonitis.*—Any of the above lesions of the appendix may be present. Serosa of the intestinal coils as far as exploration is carried shows uniform inflammatory changes: redness with diminution of lustre or deposits of fibrin or fibrino-purulent exudate. Distention of the intestine is usually found. Exudate is free, clear, cloudy, odorless or odoriferous.

6. *Acute Appendicitis with Progressive Fibrino-purulent Peritonitis.*—This term is restricted to the comparatively rare condition in which the intestinal coils as far as exploration is carried are found with surfaces glued together by organized fibrino-purulent exudate. Bleeding occurs when the attempt is made to separate the coils. Numerous pockets of pus are present between the adherent intestines.

These terms represent stages in the progress of infection of varying degrees of virulence in individuals of varying resistance discovered at operation at varying periods of time from the onset of the attack.

The following table gives the totals of the cases of the various types during the years mentioned. The cases of peritoneal abscess with accom-

panying local peritonitis are included with the first condition; those of peritoneal abscess with acute diffuse peritonitis are given in the column of the latter condition.

TABLE I

Year	Acute appendicitis	Acute appendicitis with acute local peritonitis	Acute appendicitis with abscess (peritoneal and extraperitoneal)	Acute appendicitis with acute diffuse peritonitis	Acute appendicitis with progressive fibrinopurulent peritonitis	Yearly total
1915	93	26	57	11	0	187
1916	74	30	41	11	0	156
1917	62	30	40	7	1	140
1918 To December 1	79	22	34	4	0	139
						622

Five hundred and eighty-nine of these 622 cases were operated upon, and with few exceptions, operation followed immediately upon the establishment of the diagnosis, regardless of the stage of infection. The appendix was removed, if at all accessible, and the wound either entirely closed, or mural or intra-abdominal drainage instituted.

The operator's conception of the infective status of the case determines his procedure in regard to peritoneal drainage, or closure of the abdominal wall. It is probable that in most cases of acute appendicitis a more or less active contamination of the peritoneum is in progress as early as twelve hours.[3] The great reserve power of visceral and parietal peritoneum and omentum in combating infection is called into play. Through the agency of their blood-vessels and lymphatics, these structures respond to the bacterial insult, and during the interval preceding operation may afford adequate protection of the peritoneal cavity at large. The fact that many cases survive one or more attacks of acute appendicitis without operative interference testifies to the very considerable power of the peritoneum in dealing with infections. This knowledge gives the surgeon confidence in closing the peritoneum after removal of its infecting focus, in dealing with the lesions of the first type (acute appendicitis) and early or mild cases of the second type (acute appendicitis with acute local peritonitis). In many instances, however, the wall of the appendix early becomes badly compromised and the bacterial invasion thrown upon the peritoneum is so great that its defensive mechanism is strained or overtaxed. An intense, local peritonitis usually appears in response to the injury, and a peritoneal exudate rich in bactericidal elements is thrown out. With a heavy bacterial contamination, phagocytosis can-

[3] E. Moschcowitz: The Pathological Diagnosis of Diseases of the Appendix Based on the Study of 1500 Specimens. ANNALS OF SURGERY, June, 1916.

not keep pace with bacterial growth, and the exudate rapidly becomes foul and purulent. It is this transitional stage between contamination and progressive infection, between a strained and an overtaxed peritoneum that constitutes the border line between those cases that may be closed safely and those in which intraperitoneal drainage seems a necessity. If the peritoneal cavity be closed, one must feel reasonably certain that the residual infection will be taken care of without even the formation of a localized abscess. The infective status of the case must be determined from a consideration of the condition of visceral and parietal peritoneum, the omentum and the character of the exudate present. Briefly, if the peritoneum over a considerable area shows a definite disappearance of gloss or is covered by fibrino-purulent exudate, and the free exudate is odoriferous, indicating a decline in its bactericidal properties, most surgeons decide upon intraperitoneal drainage. The condition of the appendix, if removable, is of secondary importance.

If infection has progressed to the stage of intraperitoneal abscess, drainage becomes almost imperative. There was but one exception to this rule in the cases reviewed. In this instance, empyema of the appendix was present and there was a small amount of odorless, creamy pus about the appendix; the visceral peritoneum did not appear compromised. Following removal of the appendix and evacuation of the abscess, the peritoneum was closed. The procedure was followed by a favorable outcome. Culture of the pus proved sterile. While occasionally it is possible to differentiate a "cold" abscess of this type, and despite the probability that outlying pus pockets in advanced infections are occasionally taken care of by the peritoneum, it would seem more the part of wisdom to make provision in these cases for escape of any necrotic tissue that may line the cavity.

The advisability of drainage in acute appendicitis with diffuse peritonitis is often questioned. The picture indicates that the mass of infection is great or the resistance of the individual below par. Whether drainage from the general peritoneal cavity continues for an hour after operation or for one or two days,[4] it would seem advisable to afford the peritoneum whatever advantage drainage may give. In some instances adhesions about the drainage tubes probably form as rapidly as fibrin can be deposited between the surrounding coils and escape of infective exudate is slight; on the other hand, it is possible that there may be but little attempt at adhesion formation and the fluid from a considerable part of the cavity may find exit for a more prolonged period. While it is doubtful if conclusions of much value may be drawn from infections in dogs, it was interesting to observe the entire absence of adhesions in one case of diffuse peritonitis autopsied twenty-four hours after drainage.[5]

[4] Murphy, J. B.: Quoted by F. Matthews, Johnson's "Operative Therapeusis."

TABLE II

Year	1915.....	1916.....	1917.....	1918..... (11 mos.)	Totals...
Acute appendicitis	93	74	62	79	308
No operation	11	9	6	6	32
Appendicectomy	69	56	44	58	227
Appendicectomy with mural drainage	11	4	9	11	35
Appendicectomy with peritoneal drainage	2	5	3	4	14
Secondary infection wound	5	5	6	1	17
Hospital stay—average	262 cases; peritoneum closed				12.5 days
Deaths	1	1	0	0	2 0.0065%
Acute appendicitis with acute loc. peritonitis	26	30	30	22	108
Appendicectomy	6	5	10	3	24
Appendicectomy with mural drainage	2	2	2	2	8
Appendicectomy with peritoneal drainage	18	23	18	17	76
Secondary infection wound	2	3	0	1	6
Hospital stay—peritoneum closed	32 cases				14* days
Hospital stay—peritoneum drained	65 cases (Dakin [6] not incl.)				22.2* days
Deaths	2	1	0	2	5 4.6%
Acute appendicitis with abscess, peritoneal and extraperitoneal	57	41	40	34	172
Appendicectomy with mural drainage	0	1	0	0	1
Appendicectomy with peritoneal drainage	50	37	38	31	156
Incision and drainage	7	3	2	3	15
Hospital stay—average	148 cases (Dakin cases [23] not incl.)				27.2 days
Deaths	5	4	1	2	12 7%
Acute appendicitis with acute diffuse peritonitis	11	11	7	4	33
Appendicectomy with peritoneal drainage	11	11	7	3	32
Hospital stay—average	22 cases (Dakin cases [23] not incl.)				41.2 days
Deaths	1	5	2	0	8 25%
Acute appendicitis with prog. fib. pur. peritonitis	0	0	1	0	1
Appendicectomy with drainage	0	0	1	0	1
Deaths	0	0	1	0	1 100%

* Average all cases 19.1 days (Dakin except).

Finally, in the cases of acute appendicitis with progressive fibrinopurulent peritonitis, if operation is attempted, the advisability of drainage cannot be questioned

Closure of the peritoneum and drainage of the tissues of the abdominal wall is a practice which arose as a result of the observation that in certain cases of acute appendicitis with a degree of localized infection that might be safely controlled by the peritoneum, the contamination of the wound during operation led to its secondary infection. In other words, it is a recognition of the lesser ability of the structures of the abdominal wall to deal with the infecting organisms.

The accompanying Table II represents dispositions of the cases of Table I, together with secondary infections occurring in the first two groups, duration of hospital stay, and mortality.

Conclusions as to duration of suppuration, time of hospital stay, secondary procedure, condition of wound on discharge, subsequent ventral hernia, etc., have been prepared from a tabulation of the 263 cases. There are certain reasons why deductions from the total number of drainage cases should prove more fair and valuable than those drawn from arbitrary groups. A very large percentage of the cases in which intraperitoneal drainage was used were those of advanced infection. Many of the 71 cases classed as acute localized peritonitis had free foul pus and their subsequent course in certain instances seemed to be that of a diffuse peritonitis; 178 had definite abscess formation; 33 cases were classed as acute appendicitis with acute diffuse peritonitis, some of these having one or more subsequent abscesses. The inclusion of a comparatively few minor infections in a group of 263 cases does not affect percentages and places the error to the credit side of the cases treated by simple drainage when we compare results with cases treated by the antiseptic method. A composite view of the disease in its severer form is what one wishes to obtain as a criterion in determining the value of any method of treatment. While the impression made by the pathology of the case rarely deceives the surgeon as to advisability of drainage, a careful reading of the data of operation and post-operative course often leads one to view with suspicion the diagnosis accorded the case. Table II is in consonance with the corrected hospital records. The review of these case histories brought to light numerous errors, in the correction of which the cooperation of several members of the staff was enlisted. Despite the fact that a very considerable amount of time and care was given to this work I do not feel that even now the placing of cases in all instances is free of error or could be rendered so from the recorded data. Reference to the table of case groups is of value in indicating the comparative uniformity of infections received from year to year.

[6] Rulison: A Study of the Intra-abdominal Use, etc., *ibid.*

REVIEW OF 263 CASES OF ACUTE APPENDICITIS WITH INTRAPERITONEAL DRAINAGE

Type of Incision.—This is of interest only as indicating accuracy of diagnosis and from the standpoint of hernia. The intermuscular incision of McBurney was used in 176 cases (67 per cent.); the intermuscular incision with extension into the right rectus sheath (Weir) in 43 cases (17 per cent.); the right rectus incision through the muscle in 30 cases (11 per cent.). The incision through anterior rectus sheath with retraction of rectus muscle towards mid-line (Kammerer) was employed in 2 cases and the transverse incision (Rockey) in 3 cases. A median vertical incision indicating either advanced peritoneal infection or doubt as to diagnosis was used in 9 cases (3 per cent.). An additional stab wound in right flank for dependent drainage of the lumbar gutter was made in 10 cases (3.8 per cent.). Ventral hernia was noted in 21 cases in which the intermuscular incision was used, 6 cases in which the Weir incision was used, and 6 in which the right rectus incision was used. Bulging at the site of scar, not classified as hernia, was present in 18 of the intermuscular cases, 7 of the Weir extension cases, 3 of the rectus and one median. In percentages weak wall or hernia occurred in 22.3 per cent. of intermuscular, 29 per cent. of rectus, and 30 per cent. of Weir extension. There were several instances in which weak wall at site of intermuscular scar with definite bulge improved during the interval of follow-up visits and eventually disappeared. This has been attributed to muscular hypertrophy occurring as the patient resumes active exercise. The larger percentage of hernia in rectus incisions was expected, owing to the pull exerted on the wound by the lateral abdominal muscles. Incision into the rectus sheath also appears to add somewhat to the possibility of hernia.

Pathological Findings at Operation.—Reference to Table II indicates in general the broader phases of pathology presented.

Condition of Appendix.—Not located in 13 cases (4.2 per cent.); apparently not more involved than regional peritoneum, but classed as acute appendicitis in 1 case; acutely inflamed, but not gangrenous in 56 cases (21 per cent.); gangrenous in 185 cases (70 per cent.); perforated in 88 cases (34 per cent.); thrombosis of vessels of meso-appendix in 10 cases (3.8 per cent.); abscess of meso-appendix, 3 cases.

Exudate.—Clear, free fluid was noted in 10 cases, cloudy free fluid without odor in 63 cases, free foul exudate in 14 cases, pus not localized in 32 cases. In 137 of the 178 cases with abscess the size of the collection was recorded; of these, 65 were collections of more than two ounces; 72, collections of less than two ounces. Multiple pus pockets were present in 9 cases (3.4 per cent.). Odorless pus was noted in 22 instances, foul pus in 130 instances, or nearly 50 per cent. of the total group.

The various locations of the appendix and pus collections are of interest and importance from several viewpoints. In several of the cases

with acute diffuse peritonitis, rapidly terminating fatally, the appendix has been found lying free on the pelvic brim or in a mesial direction. On the other hand, with very few exceptions, the retro-, latero- and subcæcal positions have given rise to a more localized peritonitis and have favored circumscribed abscess formation. Our records of the past four years are in consonance with the opinion, often expressed, that the rapidity of the development of symptoms and the clinical course of the case is dependent largely upon the position of the appendix.

The location of the pus collection is of particular interest in considering drainage procedures and will be referred to under that heading. The following is a summary of the various abscesses recorded in the 263 cases reviewed.

Extraperitoneal abscesses: Laterocolic, 4; retrocæcal, 5; retrocolic, 3.

Peritoneal abscesses: Laterocolic, 18; mesiocolic, 15; pelvic, 54; procæcal, 10; retrocæcal, 41; subcæcal, 21; subhepatic, 3; right hypochondriac, 1.

The yearly totals of these various appendix and abscess locations show a very marked close uniformity.

Œdema of the properitoneal tissues was noted many times, but definite cellulitis of abdominal wall tissues was recorded in but 7 cases. This is strong evidence of the view that prior to operation the abdominal wall may be said to be free of gross infection.

Bacteriology.—Cultures of exudate or pus were taken in 189 of the cases, at the time of operation. These, for the most part, were aërobic only. Thirty cultures (16.3 per cent.) proved sterile. In nearly every instance these were exudate cultures obtained in the acute appendicitis or acute appendicitis with acute local peritonitis groups. In only two instances were organisms present on smear which failed to grow. The following is a list of organisms recovered either alone or symbiotically.

B. Coli Communis, 114 of 116 positive cultures (71 per cent.) B. Coli Communis, 3.

Streptococcus (not further differentiated), 75 times—47 per cent.

Streptococcus hæmolyticus, 5 times. Streptococcus non-hæmolyticus, 17 times.

Some form of streptococcus was recovered in 97 cases, or 60 per cent.

Staphylococcus, 18 times—11.3 per cent.

Of the rarer forms recovered: Bac. Friedlander, 4; Pyocyaneus, 4; B. Proteus, 4; B. Lactis Aërogenes, 5; B. Fecalis Alkaligenes, 3; B. Mucosus Capsulatus, 3; Pneumococcus, 2; Micrococcus Tetragenes, 1; B. Paratyphosus, 2; B. Diphtheriæ, 1; Gram-negative bacillinot further differentiated were reported in 10 cases; Gram-positive bacilli in 6 cases; Gram-positive coccus in 5 cases.

The association of some form of streptococcus with the colon bacillus was by far the most common (44 cases).

The association of streptococcus with B. Pyocyaneus, B. Friedlander, B. Fecalis Alkaligenes was observed in several instances.

Pure cultures of B. Coli Communis were reported in 42 cases; pure cultures of some form of streptococcus in 13 cases. Pure cultures of staphylococcus aureus and albus and B. Coli Communis were also reported.

The type of organisms recovered at operation does not seem to furnish any information of prognostic value. The various symbioses noted above were found alike in mild and severe grades of peritoneal infections. Cultures were taken in 6 of the 8 fatal cases with acute diffuse peritonitis with the following results:

History No. 32100; death two hours after operation. Streptococcus.

History No. 35951; death twelve hours after operation. Gram-negative diplococcus; Gram-negative bacillus; staphylococcus.

History No. 31879; death sixteen hours after operation. Bac. Coli Communis; streptococcus.

History No. 35468; death four days after operation. Bac. Paratyphosus.

History No. 21685; death seven days after operation. Bac. Pyocyaneus; Bac. Coli Communis, B. Proteus.

History No. 31294; death seventy-four days after operation. Streptococcus non-hæmolyticus.

Cultures were made in 16 of the 22 recovered cases of the same group. Six pure cultures of B. Coli Communis and five cultures of Bac. Coli Communis with some form of streptococcus were reported. In the remaining 5 cases there was a pure culture of streptococcus; Bac. Coli Communis with B. Fecalis Alkaligenes; Bac. Coli Communis with a staphylococcus (2 cases); B. Coli Communior with a Gram-positive diplococcus.

Methods of Drainage and Post-operative Care of Wounds.—There is probably no common surgical condition that is more variously treated than the one under consideration. The cases reviewed were those of fifteen operators, and the manner in which the cases were handled was varied, both from the standpoint of the different operators, and also in regard to similar cases of the same operator. The inference that may be drawn is that, as in any condition in which the therapeutic measures employed are legion, no one is entirely satisfactory. Each operator's procedure is necessarily based upon his surgical training and experience. The tendency to standardization of treatment was especially noticeable in reading the cases of the operators of longer surgical experience. The cases were tabulated in such a manner that the results of operators using different methods might be determined. For example, Surgeon A. invariably placed a cigarette drain to pelvis and a gauze drain to stump of appendix which was tied off. His post-operative wound cure was an early removal of the gauze drain and a late removal of the cigarette drain with only occasional irrigation of drainage tract. Surgeon B. invariably placed a single large calibre, thin-walled, soft rubber drainage tube to pelvis and on the second or third day substituted a soft rubber catheter through which the tract was irrigated daily by salt solution or boric solution. Each operator had about the same number (28 and 30) of cases

extending over the past four years, and their cases compared closely in type. A comparison of their results will be taken up later.

In reviewing the cases of the men of shorter experience, changes in procedure from case to case was particularly noticeable. Surgeon C., for example, was having very good results with rubber tube drainage, loosening the drain on the first or second day, removing it about the fifth to irrigate the tract, and then replacing it daily until discharge was diminished and tract clean. One of his cases develops a fecal fistula with the drain still *in situ* on the tenth or twelfth day. A discussion occurs at the bed-side and the rubber tube is blamed, perhaps justifiably. In his next few cases he either removes the rubber tube earlier or substitutes at operation a cigarette drain for the tube. If he decides to remove the drain earlier or shorten it a half inch daily, all goes well until some case develops a residual abscess at the depth of the tract; if he has transferred his allegiance to cigarette drains he may soon become dissatisfied on observing the inefficient drainage; an outpouring of an ounce or two of dammed-back pus on removal of the drain.

The results of the operators of long experience using standardized technic and not disturbed by the occasional wound complication, were, in general, better than those of men either attempting to individualize in their cases, or occasionally employing methods aimed at circumventing certain complications. Strangely enough, under the simple (as opposed to antiseptic) method of treatment the results attained under standardized but diametrically opposed methods were about the same.

There are certain underlying principles which all surgeons have in mind in the treatment of appendiceal infections. If at operation a well walled-off collection of pus is found and entered without contaminating the general abdominal cavity, the appendix is removed, if this can be done without breaking up protective adhesions, and the infected locality is drained. If free pus is present it is usually found in the pelvis and right lumbar gutter and drains are placed to these regions. As a rule, the drains are allowed to extend through the operative wound. Many have advocated and several practiced the separate drainage of the right lumbar gutter through a stab wound in the loin. The rationale of this procedure is unquestionably good from an anatomical viewpoint, as true dependent drainage is only in this way obtained. There have been no cases of vaginal or rectal drainage in this series. The drainage from the pelvis through tubes protruding from the abdominal wound is vertically upward with patient in Fowler or Gatch position. On the other hand, tubes to the right lumbar gutter in these positions have a horizontal direction or a few degrees of downward inclination. There were ten cases in which loin drainage was employed. All had retrocæcal, retrocolic or laterocolic abscess, three having retroperitoneal abscesses. Three cases resulted fatally, one from tuberculous broncho-pneumonia, the other two as a result of their infection which in each instance was of a severe

grade. In the 59 cases of latero- or retrocæcal and retrocolic abscesses drained through the anterior wound, drain was placed to the right lumbar gutter in 13 instances, and there was 1 death. This, at least, does not support the claims of decreased mortality made by some in favor of stab-wound drainage. On the other hand, it does not constitute a valid objection to its employment. Perhaps a greater argument than dependent drainage that might be urged in favor of loin drainage is that it permits the establishment of a straight tract. A drain placed to the lumbar gutter and emerging from an intermuscular or rectus incision must necessarily describe a curve, and the tube is therefore prone to buckle and prove inefficient. Tortuous tracts are often handled with success by late removal of the drain or the substitution of a small catheter after a few days, but they usually prove a worry.

Fenestrated, thin-walled, soft rubber tubes are to-day generally recognized as combining the highest grade of efficiency in drainage with the least danger of harm to the infected intestinal wall. The cigarette drain (gauze wapped with rubber tissue, rubber dam or gutta percha), while causing less pressure on contacting intestine, is quite worthless as a drain after a few hours. That cases do well with cigarette drains *in situ* is due to escape of exudate about the drain after it has been loosened, or, if multiple drains have been introduced, after the removal of one of them. In comparing the results of surgeons A. and B., the former, using cigarette drains, had 3 cases of fecal fistula in 30 cases; surgeon B. substituting a catheter for rubber tube drain on the second or third day had no fecal fistulæ develop in his 28 cases.

The type of drain most frequently employed was the double-arm tube, devised by Dr. Joseph A. Blake. The tube is so fashioned that the deep ends of the two arms are held together by a narrow connecting portion of the tube wall. One arm is fenestrated and provided with a gauze wick which affords capillarity between the depth of the tract and the wound dressing. The wick also tends to prevent possible insinuation of a process of omentum into the lumen of the tube. The other arm is non-fenestrated and left open; it provides another avenue of escape of exudate, and permits the introduction of a catheter for irrigation at the daily dressing. Tubes of this type were used in 114 of the 263 cases (44 per cent.). Single fenestrated tubes with gauze wick were employed either alone, with the double arm tube, or multiple single tubes in 97 cases (37 per cent.). Cigarette drains, single or multiple, alone or with rubber tubes in 73 cases (28 per cent.). Gauze drains were employed in 22 cases and only as an adjunct to other drains, and were invariably removed early. Other drains occasionally employed were rubber dam in 4 cases, small rubber tubes inclosed in silk in 2 cases, Mikulicz drain in 1 case, and rubber tissue in 1 case.

Drain was placed to pelvis either alone or with drain to other regions in 144 cases (54.7 per cent.); to cæcal region in 119 cases (45.2 per cent.);

to right lumbar gutter in 23 cases (9 per cent.). In 10 cases a lumbar gutter drain was introduced through a stab wound in the loin. In 37 cases drains were placed both to pelvis and cæcal region. In a few instances other regions were drained, as the pathology required, *e.g.*, subhepatic abscesses. One subhepatic abscess was drained with success through the intermuscular incision, although the tract was necessarily a very long and a sharply angulated one. In one case the drain was placed just within the peritoneum, the abscess being procæcal. Drains in the superficial wound were introduced as adjuncts in 9 cases.

The post-operative care of the wound was various but found to resolve itself into (1) a loosening and gradual and progressive shortening of the original drains; (2) early or (3) late removal and replacement by the same size or smaller size drains or catheter, the wound usually being irrigated by saline or boric solution at the daily dressing. The first method of gradual shortening was employed in 62 cases (24 per cent.); in some of these cases a small drain was introduced after the late removal of the original drain. In 102 cases, 38.8 per cent., the original drains were removed and replaced either by the same or smaller tube during the first four days; in 111 cases (42.2 per cent.) replacement was effected subsequent to the fourth day. Daily irrigations were the rule in the tube-drain cases. With the double-arm tube this was accomplished early, before removal of drain, by loosening and slightly withdrawing drain and the introduction of the irrigating catheter to the depth of the closed arm. After a period of four to five days, the double tube was frequently removed, a catheter inserted to the depth of the tract and irrigation was followed by replacement of one arm of the tube. Another method has been alluded to, of replacing the drainage tube by a soft rubber catheter early or late, and allowing this to remain in the wound as a drain, and to facilitate daily irrigation.

The progress of wound infection and repair under these varying methods of treatment was strikingly similar; the results attained by men skilled in the employment of diametrically opposed procedures were almost identical. Taking the cigarette drained cases with late replacement, or gradual shortening with occasional or no irrigation in comparison with the tube-drained cases with early replacement and daily irrigation through catheter, the former reached a stage of clinical cleanliness when drainage could be safely discontinued in the average case on the fourteenth day; the latter on the sixteenth day. Evidence of inefficient drainage was noted in two cases of the former and only one of the latter. The character of discharge and infection of abdominal wall was similar—slough of aponeurosis was noted in 8 and 7 cases, respectively. Under the former treatment three fecal fistulæ appeared; one of these occurring in a tuberculous subject in which a tuberculous peritonitis was found at a later operation; no fecal fistula occurred in the latter. There was one case of secondary abscess under each type of treatment. Thrombophlebitis of internal saphenous vein occurred once in each group. The

wounds on discharge showed an interesting variation in the former, but three cases having a discharging sinus, in the latter seven cases. In general, however, the wounds showed similar stages of healing. The average hospital stay was twenty-three days in each. One death occurred in each. The follow-up cases yielded similar results in herniæ and weak abdominal walls.

In a perusal of the dressing notes of many of the cases, one cannot but be impressed by the number of manœuvres which were decidedly painful to the patient, and the net gain of which proved to be extremely small, if any. The practice, which has been rather common, of removing a large drainage tube from a deep tract which in many cases proved to be more or less tortuous, irrigating the tract and then attempting to reinsert the same tube, should certainly be condemned. The objections, if any, of replacement by a small drain are more than offset by the possible injury that may be done to the delicate wall of the drainage tract and the suffering caused by instrumental introduction of a large tube. With the technic of antiseptic treatment described in another paper,[6] the patient can be said to enjoy complete freedom from painful dressings.

Viewed in the light of the post-operative course of the cases treated throughout by the introduction of adequate quantities of Dakin's fluid, the greater number of these 263 cases treated by simple drainage present an unattractive picture. It is quite analogous to the startling change said to have been made in the course of war wounds when treated either by débridement or by the Carrel-Dakin method.

An effort has been made to summarize the course of the cases as a whole, in regard to efficiency of drainage, wound complications, degree of suppuration, and destruction of abdominal wall tissues, including wound disruptions. There were 36 cases (14 per cent.) in which wound drainage was inefficient, evidenced by the sudden outflow of a considerable quantity of exudate on loosening or removing the drain. The causes were various: cigarette drains acting as plugs, buckling of the rubber tubes and clots of fibrin within the lumen of the tubes were found the more common. Hemorrhage from the wound occurred in 7 cases (2.7 per cent.); in one case a fatal issue was barely averted by transfusion and secondary operation for control. Hemorrhagic oozing was present in two other cases. It was possible to ascertain the degree of suppuration in 207 cases. Slight suppuration throughout was recorded in 19 cases (9 per cent.); moderate in 55 (26.5 per cent.), and profuse in 133 (64.5 per cent.). Odorless discharge was noted in but six of 179 cases (3.3 per cent.); foul discharge at some period of the post-operative course in 173 cases (96.7 per cent.). The presence or absence of slough was recorded in 143 cases. In 11 cases only did the histories indicate an absence of slough. In 31 cases

[6] Rulison. E. T., Jr., M.D.: The Clinical Application of the Carrel-Dakin Method to Cases of Acute Appendicitis Requiring Drainage.

the slough was evidently superficial or from the abscess wall; in 100 cases there was a definite necrosis of the aponeurosis of the external oblique (70 per cent.). While at first glance this percentage may seem high, it was arrived at by as fair an interpretation of the records as was possible. A large number of cases in which dressing notes were meagre undoubtedly had slough of aponeurosis, but, of course, have been excluded. I believe that the number of cases of this kind excluded more than offsets the number in which no slough had occurred. That the sloughing out of the aponeurosis has been considered rather in the normal course of events in these drainage cases receives confirmatory evidence from the history notes. For example, in History No. 22071, on the sixth day "considerable slough removed from wound," and on the eighth day "sloughs are beginning to separate," and on the twelfth day "tubes placed to depth of pelvis relieving pocket at deep portion," and on the twenty-fifth day "patient leaves hospital with a discharging sinus, having made *an uneventful recovery.*" In History No. 30374, on the eighth day a note was made of "considerable slough," and on the tenth day "large piece of sloughs removed;" on the forty-second day "wound healed with crust. sinus, having made *a good recovery.*" In History No. 37256, on the tenth day "one slough of external oblique removed;" on the eleventh day "large sloughs removed;" on the twenty-fourth day "wound healed with crust. He had a *characteristic sloughing* of the wound with loss of much external oblique aponeurosis, leaving him with probable chances of ventral hernia."

A recent house surgeon asserted that during his service he had never seen an appendix abscess which had not sloughed out a portion of the aponeurosis. To quote from the records of some of the cases not making as good recovery as those cited above, in History No. 20366, on the fourth day "wound lined by slough, caput coli presenting;" on the ninth day, "cæcum bulged into wound and was packed back." In History No. 20602, on the sixth day "several sloughs removed;" on the eighth day "internal oblique separated 1 inch, intestine in wound." In History No. 33978 on the seventh day "much slough;" on the ninth day "great many stinking sloughs removed;" on the eleventh day "condition of wound fair, no sloughs." In History No. 36281, on ninth day, "large piece of slough;" on tenth day "several pieces of slough;" on the fourteenth day, "large piece of slough *with chromic sutures;*" on sixteenth day, "large pieces of slough." In History No. 37242 on the eleventh day "cellulitis with disruption of wound;" on the 13th day "enormous amount of slough, mostly aponeurosis, removed;" on the twenty-first day "one piece of slough." In History No. 33638, on the eighth day, "fecal fistula has appeared;" on the tenth day "gut in wound;" on the fourteenth day "wound a granulating cavity formed by coils of intestine and abdominal wall. Skin edges show effect of sloughing, having an irregular worm-eaten edge. Discharge a bright yellow liquid with curds." In History No. 20734, on the fifth day, "wound wide open, lined by sloughs; aponeurosis sloughing away;" on the seventh day "con-

siderable slough;" on the ninth day "abscess beneath the abdominal wall opened by finger drain;" on the tenth day "sheath of rectus entirely sloughed out." These quotations were taken almost at random from the 100 cases in which slough of aponeurosis was recorded. The character of discharge present, the foul, stinking "colon" odor that greets the surgeon when the bedclothes are turned down at the daily dressing, the odor that the patient has to endure for a period of a week or ten days and often longer, is familiar to all. The dressing notes abound in vivid characterizations of the odors emitted by the wounds.

Actual hernia of intestine into wounds was referred to in 9 cases, and a more moderate degree of wound disruption in 12. Mural abscesses occurred in 17 cases.

The average period of suppuration was estimated in 204 cases as 15.4 days. At the end of this period the wound might be said to be "clinically clean" and necessity of drainage no longer present.

Complications.—Fecal fistulæ appeared in 18 cases, or 7.5 per cent. of the cases which recovered. There were two fistulæ among the 24 fatal cases. Twelve fistulæ closed spontaneously; two were closed by operative procedure and five failed to close. Three cases were discharged from the hospital with fecal fistula, one of these after an unsuccessful operative attempt at closure.

Analysis of these 18 cases of fistula yields the following data: In 10 cases rubber-tube drainage was employed, in 5 cases cigarette drains, and in 3 cases both rubber tubes and cigarette drains. In 15 cases the postoperative wound management consisted of a gradual shortening or a late replacement of drains by smaller drains or reinsertion of the original drain. In only two cases in which the original drain was early replaced by a small drain, that is, before the fourth day, did fistula develop. One of these two cases, History No. 35099, was treated by removal of the cigarette drain on the second day and attempt at replacement by a catheter failed. The case began to show a mounting temperature and on the fourth day a catheter was passed instrumentally in a direction the original drain had taken for a distance of six inches. On the tenth day a rubber tube was substituted and on the following day a fistula appeared. Evidence of injury to the drainage tract by forcibly introducing drains was found in 4 cases. There was one case of fistula resulting from deliberate opening of a knuckle of intestine in wound to relieve ileus.

Consideration of these findings lends evidence to the views generally held regarding the development of this complication. The prolonged tube pressure against an infected intestinal wall undoubtedly causes an area of localized necrosis. The very low incidence of fistula in cases treated by an early substitution of a smaller drain or catheter is strong confirmatory proof of this view. The importance of handling abdominal drainage tracts with gentleness is emphasized by the appearance of fecal fistula in 4 of 16 cases in which secondary wound procedures were necessary

to improve drainage. In the antiseptic treatment of drainage tracts described in another paper[7] these considerations are given due weight. Efficient contact of antiseptic with tract wall necessitates the early exchange of tube for catheter which is introduced with minimal injury to the tract wall. The tendency to restraint of infection afforded by the antiseptic may also prove a factor in lessening wall destruction.

Of the strictly abdominal complications, *secondary abscesses* furnished the greatest number. The 17 cases of mural abscess have been mentioned. There were 21 cases of secondary peritoneal abscess (8 per cent.), 12 in pelvic position, 3 subphrenic, 2 subhepatic, 2 right lumbar, 1 in subsplenic, and 1 in left lower abdomen. Spontaneous evacuation resulted in 3 cases through wound and in 1 case by rectum. Eleven secondary collections were drained by approach through wound, usually the insertion of a finger with patient under nitrous-oxide-oxygen anæsthesia. Six were drained through separate abdominal incisions. Abdominal masses thought to be secondary abscesses disappeared spontaneously in 3 cases.

Paralytic and mechanical ileus were comparatively rare complications, the former occurring in 7 cases (2.6 per cent.) and the latter in but 3 cases (1.1 per cent.). This excellent record is due, it would seem, to the close observation that the cases receive and deserve, and the prompt institution of treatment directed towards relief of complications. In general the management of a case with peritonitis of any degree has been to allow little or no fluids by mouth, colonic irrigations at intervals of six or eight hours, beginning about 12 hours after operation, gastric lavage repeated at intervals of six or eight hours if vomiting or distention indicate. Deficiency of fluids has been met by proctoclysis, hypodermoclysis, intravenous infusion of normal saline or glucose solutions. The withholding of fluids or food by mouth until gastro-intestinal peristaltic movements have become orderly usually affords the patient a course uncomplicated by paralytic ileus. Care in the placing of drains is, of course, an important prophylactic measure for ileus of mechanical type. The proper beveling of drainage tube ends and the compressibility of the tube walls are details of no little importance. When we reflect that it is asserted that it requires but a weight of 5 to 8 grammes to check the onward movement of contents in the dog's normal intestine,[8] it is surprising that in these infected cases we meet the condition of mechanical ileus so infrequently.

Of the 10 cases of ileus, there were 3 deaths due to failure to relieve the condition. Of the 7 recovered cases, 4 recovered without surgical intervention and 3 after operative procedure for relief. Of the 4 recovering without operation, 3 were of paralytic variety, the other what was thought to be an early mechanical ileus. Two of the three cases recovering after operation were of the mechanical type. None of the mechanical ileus cases died of

[7] Rulison, E. T., Jr., M.D.: The Clinical Application of the Carrel-Dakin Method to Cases of Acute Appendicitis Requiring Drainage.

[8] Cash: Johns Hopkins Hospital Reports, i, 93, 1896.

the condition. Operation revealed adhesions with kinking of the intestine in one case, and obstruction from tube pressure in the other. Paralytic ileus in the three fatal cases was a terminal condition, a symptom of the unchecked progressive infection. In only one of these cases was operative relief attempted.

There were 3 cases of acute dilatation of the stomach, all being relieved by lavage and change of position.

Of the complications not immediately abdominal, those of the respiratory tract were most numerous. Acute bronchitis occurred in 2 cases, post-operative pneumonitis of lobar type in 17 cases (6.4 per cent.); broncho-pneumonia in 2 cases; empyema in 4 cases; pulmonary infarction in 3; pulmonary embolism in 2; pulmonary tuberculosis in 5 cases, making a total of 36 pulmonary complications, or 13.7 per cent. This high percentage, I believe, has not been generally recognized.

Urinary complications were infrequent; acute cystitis in 2 cases and acute uræmia in 2 cases.

Blood-vessel complications comprised 2 cases of thrombophlebitis of the internal saphenous vein and 1 case of embolism of the femoral artery with gangrene of the extremity; pylephlebitis occurred in one case.

Jaundice was present in 4 cases; acute exanthemata in 2 cases; a toxic erythema in one case that also suffered from an infectious psychosis. Acute rheumatic fever complicated 1 case; otitis media, 2 cases; entercolitis, 2 cases. There were in all a total of 62 complications (23.6 per cent.) not immediately abdominal in character.

History No. 22301 serves as an illustration of the manner in which some cases may be beset by complications At operation a gangrenous appendix with a large amount of free pus in the pelvis and right lumbar gutter was found. Visceral and parietal peritoneum showed pathological changes as far as exploration was carried. Operative diagnosis was acute appendicitis with acute diffuse peritonitis. Appendix was removed and a double rubber tube drain was placed to pelvis and a single tube to the right lumbar gutter. Culture showed Bac. Coli Communis and B. Fecalis Alkaligenes. The wound treatment consisted of loosening and shortening the drains a little on the second day and applying a camphor-wet dressing. On the fourth day the tubes were further shortened and the wound irrigated. Discharge from wound was foul dirty brown to light yellow during the first week and profuse green to thick mucoid during the second week. By the eighth day the wound was gaping and lined by slough. On the twelfth day the cæcum lay exposed in the wound with muscles widely separated; on this day an abscess pocket in the pelvis was opened through the wound. On the fifteenth day a subcutaneous abscess was opened through the wound. On the eighteenth day a secondary abscess to the inner side of the wound between peritoneum and muscles was opened through the wound. On the forty-first day a left thoracotomy was performed for em-

pyema (culture streptococcus). On the forty-eighth day, fecal fistula appeared; on this same day a residual abscess subsplenic was opened through a left-sided incision. On the fifty-seventh day a small intestinal fistula appeared in the left side of the wound. This fistula closed spontaneously; the cæcal fistula was closed successfully by operation at the fifth month. The patient left the hospital after a stay of 205 days. Three years after the operation he was found to be in good general health. Ventral hernia was present.

Secondary procedures instituted for relief of immediate or remote complications totalled 43 (16.4 per cent.). The following is a list of these operations:

Secondary abscesses (mural or peritoneal)		23
Opened through wound	16	
Opened through separate incision	7	
Ileus		4
Mechanical	2	
Paralytic	2	
Fecal fistula		3
Exploratory for residual abscess not found		3
For control of hemorrhage		1
For recovery of fecolith		1
Secondary suture of rectus muscle		1
Skin-graft of wound		1
Amputation of leg (embolism of femoral artery)		1
Thoracotomy		5
Total		43

Late secondary operations will be referred to under follow-up results.

Conditions of Wounds on Discharge from Hospital.—Seventeen cases left with wounds completely healed (7.3 per cent.); 9 cases left with wound area covered by an apparently healthy crust (3.8 per cent.); 87 cases were discharged with small granulating areas at the site of drainage tract (37 per cent.); in 7 cases the granulating area was a large one (3 per cent.); in 43 cases a sinus was present, but discharge negligible (18.5 per cent.); in 66 cases a discharging sinus was noted (29.1 per cent.); 3 cases left with a fecal fistula in one of which operative closure had been unsuccessful. In 8 cases the condition of wound on discharge was not recorded.

The general condition of patients on discharge was good. In a few instances (four) the records state that "patient has lost considerable weight during stay in hospital." The weight of patients on admission and discharge has not been recorded in any of the cases.

The average duration of the hospital stay of the 240 recovered cases was twenty-six and five-tenth days. Late secondary procedures, *e.g.*, repair of ventral hernia, appendicectomy, etc., added one and five-tenth days to the average, making twenty-eight days. The shortest stay was eleven days; the longest two hundred and five days.

Deaths.—There were 24 deaths in the 263 cases; one occurring after a

late secondary operation (subsequent hospital admission), making 9.1 per cent. mortality. The mortality of the different groups is given in Table II.

Fifteen deaths were directly attributable to the peritoneal infection. Pulmonary embolism was given as the primary cause of death in 3 cases. In one of these at autopsy a thrombosis of right and left internal iliacs and infarcts of lung were found. Embolism of the femoral artery with gangrene of the leg and deep sacral decubitus caused death in one case. Pylephlebitis, tuberculous broncho-pneumonia, inanition as a result of a high intestinal fistula, and long continued sepsis resulting from multiple foci (subdiaphragmatic abscess, empyema with fecal fistula) were responsible for four of the deaths. One case was readmitted to the hospital after seven months with acute ileus from band, causing gangrene of a loop of ileum. Death followed resection.

Autopsies were performed in only 3 cases. One has been mentioned. The other two were cases of acute diffuse peritonitis at operation, and death in each case occurred on the seventh day. In one case there were well formed adhesions about the drainage tube but diffuse peritonitis. In the other a progressive fibrino-purulent peritonitis had ensued, numerous pus pockets and areas of necrosis were present in the intestinal walls.

Records of Follow-up Clinic.—One hundred and sixty-five of the 240 cases were followed up over a period of two months to two years (69 per cent.). The cases in which follow-up results are wanting were for the most part private patients.

The time of ultimate closure of the wound was mentioned in 36 cases and the average time after leaving the hospital estimated at five weeks.

Reappearance of discharge from wound occurred in 11 cases (4.6 per cent.). In 4 of these cases chromic sutures were expelled after prolonged periods of discharge.

Time of resumption of work in 17 cases averaged eight weeks. In 2 cases there was prolonged disability; in 1 incapacity for work existed for fifteen months.

The symptomatic results were for the most part excellent. In only 5 cases were there symptoms indicative of residual intra-abdominal pathological conditions.

The records are particularly complete in regard to the condition of the abdominal wall. The weak walls at the site of scars have been noted and described as "bulges," and the term ventral hernia reserved for cases in which a distinct neck could be palpated and definite impulse at the neck felt when patient coughed. "Bulges" or weak walls were noted in 29 cases (18 per cent.) and hernia in 33 cases (20 per cent.). The anatomical results were therefore poor in 38 per cent. of the cases.

Operations for repair of ventral hernia were done in 8 cases with 6 successful results. Hernia operations have been delayed until eight months to a year for two excellent reasons. First, there have been several cases of weak walls with decided bulges which have disappeared spontaneously

as the abdominal musculature gradually improved in tone. In one or two instances an examiner has actually recorded a hernia which at a later examination failed of verification. A second reason for delay is that pyogenic organisms probably remain enmeshed in the scar tissue of these wounds for a considerable period and militate against success in the hernial repair.

Late Secondary Operations.—In addition to the 8 operations for repair of ventral hernia, there were 3 subsequent operations for removal of appendix in cases that had previously been treated by simple incision and drainage. There was one late operation for closure of fecal fistula. Two cases re-entered the hospital with acute ileus. One has been described under deaths; the other re-entered the hospital seven days after discharge and a peritoneal band from scar to brim of pelvis was divided, the patient making a good recovery. Late residual abscesses occurred in two of the cases, one an omental abscess, admitted eleven months after discharge with history of repeated attacks of abdominal pain and symptoms of partial ileus. Omental abscess was excised and the patient left the hospital after a stay of forty-eight days. A large ventral hernia developed at the site of second operative scar. The other patient entered the hospital five months after discharge and a retrocæcal abscess containing about 100 c.c. of foul pus was opened.

There was a total of 16 late secondary operations (6.6 per cent.) with one death.

We have found in the cases reviewed that the average period of suppuration was fifteen and four-tenth days, during which time the wounds discharged foul pus and sloughs. The average duration of hospital stay was twenty-eight days. Among the frequent complications fecal fistula developed in 7.5 per cent. of the cases. Anatomical results were poor in 38 per cent. of the cases. There was a 9.1 per cent. mortality. Whether the course of these cases may be improved in any of these essential particulars by the use of antiseptics is dependent upon their safe application and a determination of their efficiency in this type of infection. A consideration of the post-operative antiseptic treatment of cases of acute appendicitis requiring drainage appears in another paper.[9]

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THE CLINICAL APPLICATION OF THE CARREL-DAKIN METHOD TO CASES OF ACUTE APPENDICITIS REQUIRING DRAINAGE[1]

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UPON the well established foundation of clinical experience in dealing with the less advanced type of peritoneal infection rests the work of Depage in the treatment of certain war wounds. The so-called "abdominal technique" has been applied successfully to the closure of lung and joint wounds as well as extensive wounds of the soft parts after removal of foreign bodies or a resection of contaminated tissues. As in dealing with appendiceal or other intraperitoneal infections, the all-important point to decide has been the degree of contamination or infection. This recent confirmation of the great value of the discrimination between contamination and infection forces upon us in a new light certain considerations which had previously been accepted as a rather inevitable accompaniment of the course of cases of acute appendicitis requiring drainage.

From a review of 263 cases of appendicitis treated at the Presbyterian Hospital during the years 1915 1918,[2] we find that under methods of simple drainage there was a failure in a large percentage (38 per cent) to preserve in a satisfactory manner the very important tissues of the abdominal wall. These tissues at the time of operation are almost without exception free from infection. During the procedure of appendicectomy and drainage of a peritoneal abscess an extensive contamination of the operative wound necessarily occurs. The time has arrived to consider the possibility of preventing this contamination from proceeding unchecked to the stage of destructive infection. It was found in the cases reviewed that the average period of suppuration was 15.4 days, during which time the majority of the wounds discharged foul pus and sloughs. The average duration of hospital stay was 28 days. Among the frequent complications, fæcal fistula developed in 7.5 per cent of the cases. There was a 9.1 per cent mortality. Whether the course of these cases may be improved in any of these essential particulars by the use of antiseptics is dependent upon their safe application and a determination of their efficiency in this type of infection.

As a result of the experimental study of certain chlorine antiseptics in localized peritoneal infections in dogs,[3] the antiseptic treatment of cases of acute appendicitis requiring drainage was undertaken first in February, 1918, as a routine in the wards of the Surgical Service at the Presbyterian Hospital.

[1] Research work under a grant of the Harriman Fund.

[2] Rulison, E. T., Jr. Drainage in appendicitis; a review of cases of acute appendicitis requiring drainage, at the Presbyterian Hospital, 1915-1918. Ann. of Surg., 1919, Dec.

[3] Rulison, E. T., Jr. A study of the intra-abdominal use of Dakin's fluid and dichloramine-T solutions with special reference to local peritoneal infections.

Aside from the eighteen cases which have been treated by the writer and which form the basis of this report, the method has been employed by others in 13 cases of appendicitis and in a number of intra-abdominal drainage tracts accompanying other conditions.

Before attempting the application of Dakin's fluid to appendiceal infections, the following conclusions had been reached in regard to the considerations involved:

1. Suture material in the intestinal wall apparently is not materially affected by small, repeated injections of Dakin's fluid.

2. Fibrin deposits occur in the presence of Dakin's fluid; adhesions walling-off intra-abdominal drainage tracts may remain effective, and healing of intestinal wounds may occur after repeated injections over a period of several days.

3. Severe pain reactions and shock attend the introduction of Dakin's fluid into the free peritoneal cavity. The use of this antiseptic must, therefore, be restricted to the treatment of the drainage tracts after the period of walling-off has occurred. The injections are, therefore, not intraperitoneal but intra-abdominal.

4. The satisfactory establishment of a water-tight drainage tract seems to depend as to its rapidity of formation upon the type of infection. The structure of the drainage tract in certain severe infections may be very precarious, even after a considerable interval. Even in the milder infections, a minimum of adventitious tissue is often present between adherent coils. Great caution as to time and manner of introducing the fluid is, therefore, necessitated. Accidents involving the integrity of intra-abdominal drainage tracts, with escape of Dakin's fluid into the free peritoneal cavity, are attended by grave danger, especially if infection be present.

5. Less slough and less foul discharge were noted in the cases treated by Dakin's fluid.

Finally, in some localized peritoneal infections in dogs, Dakin's fluid may be used with comparative safety, provided:

1. Sufficient time is allowed to elapse for a water-tight drainage tract to form;

2. Mechanical pressure of tubes or fluid upon the walls of the tract is avoided.

With these considerations in mind, the antiseptic postoperative treatment was undertaken. At first, Dakin's fluid of half strength was used and the introduction of the solution intra-abdominally was delayed for several days in order that there might be no question as to the establishment of a proper tract. In the later cases, having gained more confidence in the method, full strength Dakin's fluid has been used superficially in the planes of the abdominal wall from the time of operation and after 48 to 60 hours in the deep abdominal drainage tracts.

Attention in the 18 cases reported has been directed especially to the course of wound infection, noting the possible influence of the antiseptic in preserving the abdominal wall tissues, and in altering the course of intra-abdominal suppuration. The bacteriology of the wounds has been carefully studied, especially from the viewpoint of determining whether or not secondary suture of the wounds were possible or feasible. Many

cases have in this way received injections for many days after gross suppuration has ceased.

The contrast to the cases treated by simple drainage or by daily irrigation has been sharp, the period of discharge of foul smelling pus with shreds of slough from abdominal wall or abscess cavity in all cases being greatly lessened and in some cases minimized to a striking degree. Although the group is one of fully average severity there have been surprisingly few complications. There have been no fæcal fistulæ. No serious accidents have attended the use of Dakin's solution intra-abdominally, nor have the patients suffered pain reactions following injections, except in two late injections in one case. The patients have been discharged with better wounds, and the follow-up results to date indicate that the percentages of herniæ will be materially decreased.

DESCRIPTION OF THE METHOD

No essential change has been made in the operative technique of the cases. When possible the stump of appendix has been inverted and the site closed by a purse-string of Pagenstecher, reinforced by a figure-of-eight suture of plain catgut. In the cases with cæcal œdema precluding this treatment, the stump has been crushed and ligated with chromic catgut.

Type and arrangement of drainage tubes. A straight drainage tract is essential. We have not attempted the Dakinization of a curved or tortuous sinus and feel that any attempt to do so would be fraught with danger. A straight tract may always be obtained, e. g., in draining the right lumbar gutter, by insertion of the drains through a stab wound in the loin. In some of our cases with straight and tortuous tracts we have treated one tract with Dakin's fluid and the other by daily irrigations of saline solution.

The selection of the rubber drainage tube is important. We are using a modification of the double arm tube devised by Joseph A. Blake. The tube is of soft rubber having a wall 2 millimeters in thickness and a lumen of 6 millimeters. Instead of fashioning the tube so that the deep ends of its two arms are held together by a portion of the tube wall, two separate tubes are taken and their beveled deep ends are held together by an untied loop of plain catgut. One tube is fenestrated by means of a harness punch, the fenestrations being 3 to 4 millimeters in diameter and placed in alternating axes 2 centimeters apart. A strip of narrow gauze packing moistened with 5 per cent dichloramine-T in chloracosane is placed in the fenestrated tube to prevent possible insinuation of a process of omentum, to provide capillarity between the deep end of the tube and the dressings, and for its germicidal effect upon the organisms in the discharge (Fig. 1, A). A long bevel to the deep end of the tubes is desirable permitting a readier collapse of the walls after removal of drain, and lessening the possibility of direct pressure on intestinal walls which are in contact. The non-fenestrated or closed arm is used principally for the purpose of obtaining a larger drainage tract; it also provides freer drainage during the first 48 hours. The drainage tubes must be long enough to project an inch beyond the skin, so that they may discharge into dressings superficial to a thick non-absorbent pad (to be described).

When two drainage tracts are desirable, the double tube may be used in each or a single fenestrated tube with wick used in the shorter tract. We have also employed the single fenestrated tube alone in cases with short tracts (Fig. 3).

Great care should be employed in placing the tubes to obtain a straight drainage tract. This injunction holds good whether antiseptics are to be used or not, but is absolutely essential to the safe employment of Dakin's fluid.

Fig. 1. *a*, Modified Blake tube employed at operation for deep abdominal drainage. a^1, Cross section of tubing. *b*, Fenestrated arm of modified Blake tube, shortened at outer end and a No. 12 French catheter introduced through lumen; arrangement employed when antiseptic is first instilled in deep abdominal drainage tracts. *c*, No. 18 French catheter employed after removal of fenestrated tube for instillation of Dakin's fluid into abdominal drainage tract. *d*, Carrel tube (5 centimeter type) used for introduction of Dakin's fluid along line of sutured aponeurosis.

Closure of the abdominal wall. The peritoneum is closed about the tubes with continuous plain catgut. A tight closure is impossible because of the triangular spaces formed by the walls of the tubes and the edge of the peritoneum. These triangular spaces are closed by the introduction of narrow strips of vaseline gauze, the outer ends of which lie upon the skin surface.

The contaminated planes of the abdominal wound are now thoroughly sponged with Dakin's fluid and the transversalis and internal oblique muscles then loosely united about tubes with interrupted plain catgut. The aponeurosis of the external oblique is then closed loosely about the tubes by continuous or interrupted plain catgut, and the

skin by angle sutures of silkworm-gut. Untied sutures of silkworm-gut may be placed near the center of the wound.

The skin is now lifted by a small retractor and a 5 centimeter Carrel tube (Fig. 1, D) inserted toward the angle of the wound so that it may lie along the sutured aponeurosis. A second Carrel tube is placed along the aponeurosis toward the opposite angle of the wound. If the wound has been closed in such a manner that the drainage tubes emerge at one angle, but a single Carrel tube, of course, is required.

Separation type of dressing. The employment of the closure just described together with the separation type of dressing is an attempt to prevent the contamination of the planes of the abdominal wall from

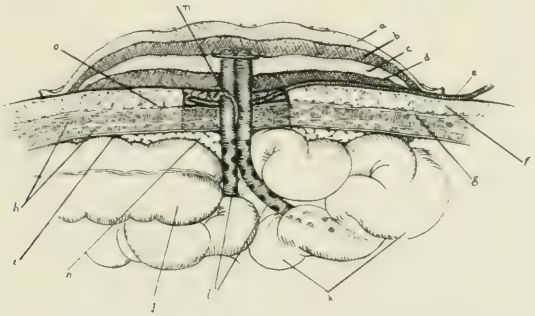

Fig. 2. Diagram illustrating arrangement of tubes and dressings at time of operation. *a*, Pad of absorbent cotton. *b*, Gauze compress layer (outer). *c*, Pad of non-absorbent cotton. *d*, Gauze compress layer (inner). *e*, Carrel 5-centimeter tube to suture line in aponeurosis. *f*, Panniculus. *g*, Aponeurosis of external oblique muscle. *h*, Muscle planes. *i*, Parietal peritoneum. *j*, Cæcum. *k*, Intestinal coils. *l*, Fenestrated soft rubber drainage tubes (closed tube to pelvis not indicated). Fenestrated tube appears too angulated. *m*, Strip of gauze packing placed in angles between tubes. *n*, Omentum. *o*, Sutures.

resulting in an infection and consequent tissue destruction. With this idea in view vaseline strips are placed upon the skin surface, in accordance with the Carrel-Dakin technique, a few gauze compresses and then a Carrel pad, consisting of a layer of absorbent cotton toward the wound and a layer of non-absorbent cotton superficially. The drainage tubes are permitted to extend through this pad and discharge their infectious material into gauze compresses placed externally. The ends of drainage tubes are transfixed by safety pins (Figs. 2 and 5).

The Carrel tubes to the aponeurosis on emerging from the wound lie flat along the skin surface and are held by a strip of adhesive to the skin of the upper abdomen. The ends of these tubes are kept covered by a gauze compress (Fig. 3).

Five cubic centimeters of full strength Dakin's fluid is injected through each of the Carrel tubes before the patient leaves the table, and a similar amount is ordered to be given every two hours night and day.

That the separation type of dressing efficiently functions during the period of its employment (48 to 60 hours) has been repeatedly demonstrated. Foul exudate has been found in the superficial dressings and thin serous exudate with a chemical odor saturating the dressings in contact with the wound. During this period it would seem that the various re-entrant angles of the wound are permitted to fill with clean

fibrin and organization may be well on its way before exudate from the deep tract is permitted to come in contact with the wound.

Postoperative care of wound. First dressing. If operation has been at night the first dressing is done on the following day at 12 to 18 hours; if a morning operation, the first dressing is at 24 hours. All dressings are carefully removed, clean forceps being used in handling dressings beneath the Carrel pad. Fresh compresses and pad are applied. The dichloramine strip is removed from fenestrated tube after application of the fresh pad and smears may be taken from its deep end. A fresh wick of 5 per cent dichloramine-T is introduced into the same tube and 1 to 2 cubic centimeters of the same solution dropped into the closed tube.

Second dressing. If this comes at 36 hours the procedure of first dressing is repeated in every detail. If the second dressing comes at

Fig. 3. Appearance of wound at the first dressing. This case was one with a short, straight tract and one fenestrated tube was used. There are two untied sutures near the center of the wound. Carrel tubes are seen entering and pass along the surface of aponeurosis toward either angle of the wound. Their free ends are held by adhesive and the tips are covered by gauze.

48 to 60 hours all wound dressings are removed including vaseline strips to peritoneum and the closed drainage tube is also removed. This is best accomplished by grasping it with an artery clamp and loosening it first by a twisting motion, thereby freeing connection by catgut loop to the fenestrated tube. Following its removal the fenestrated tube is loosened and withdrawn about 1 centimeter. It is now trimmed off close to the skin, as separation dressings are no longer used, the deep and superficial wounds freely communicating. Unless there is reason to fear that adhesions have not formed about the drainage tubes (possible in certain cases of acute diffuse peritonitis), a trial injection of saline is made by a small (No. 12 French) soft rubber catheter placed to the depth of the fenestrated tube. With a straight drainage tract, the solution should promptly return *both around and within the tube.* (Fig. 1, B.) Five cubic centimeters of Dakin's fluid warmed to 100°F. is now gently injected. A 10 cubic centimeter Luer syringe is very satisfactory as the fluid is accurately measured and the weight of the plunger is sufficient to cause fluid to run in. If the patient gives the slightest evidence of pain reaction, several hours to a day should be allowed to elapse before again

attempting injection. Pain reaction means that the tract is not yet water-tight; it means that Dakin's fluid is reaching peritoneum not protected by fibrin. In none of the 18 cases reported have we had a pain reaction at this time. Dakin's fluid warmed to 100° F. is ordered to be injected slowly and gently in 5 cubic centimeter amounts every two hours, all treatment to be discontinued immediately if patient develops a pain reaction. The instillation catheter is left in place, the outer end being held by adhesive strip to skin along with the Carrel tubes. Thus at 48 to 60 hours we may introduce full strength Dakin's fluid (Fig. 6) even in a deep pelvic tract in such a manner that it may come fully in contact with the infected tract wall. The fluid has exit both about and through the remaining tube. The wound is dressed with vaseline gauze to skin, gauze compresses, and a Carrel pad.

Fig. 4. The same wound as in Figure 3 with vaseline strips laid on the skin surface and a single gauze compress placed about the tube.

Third dressing and subsequent dressings. It is desirable to remove drainage tubes as early as commensurate with safety. With deep pelvic tracts and severe infections we have maintained the above arrangement and continued the injections by catheter within the fenestrated tube until the fourth or fifth day. In some cases we have substituted a smaller sized fenestrated tube at the third day dressing. When dealing with a short tract, a No. 18 French catheter is introduced on the third day and fenestrated tube removed (Fig. 1, c). This is easily done with no injury to the drainage tract and no discomfort to the patient by introducing it through the lumen of the tube and slipping the latter out over it.

The arrangement of catheters in the deep tracts with Carrel tubes still in the superficial wound is the final one (Fig. 7). No further changes are made until the wound is clinically clean. The dressings from the third or fourth day are extremely simple. The amount of Dakin's fluid intra-abdominally is usually increased rapidly to 10 cubic centimeters. More might be used with safety and perhaps with benefit if infection does not seem to be held in check. We have found that even in a long tract 10 cubic centimeters is amply sufficient to flush it, and that with the 10 cubic centimeters injected superficially the dressings do not become too saturated.

The Carrel tubes are usually forced out by the healing tendency of the wound about the seventh to tenth days. It is not necessary to disturb them. They may be removed, if still in place, as soon as discharge has become negligible.

Sutures are removed at the end of a week. As a rule the reaction about sutures is slight, in many cases not more than is found in a wound healing by primary union. If untied sutures have been placed at operation they may be tied when appearance of wound and bacterial count justifies.

Smaller catheters may be substituted at any time when there is indication that the tract is closing down too tightly about the original instillation catheter. In most cases we have observed this precaution about the eighth or ninth day. The only accident accompanying injection

Fig. 5. The same as Figures 3 and 4, with Carrel pad applied. The drainage tube is allowed to project through this pad of absorbent and non-absorbent cotton and discharges into the superficial gauze compresses which are applied and held by the taped adhesive straps which may be seen turned back.

in our cases occurred on the thirteenth day in a deep pelvic tract which fortunately had been clean for at least 48 hours. The walls of the tract had closed down about the instillation catheter and the injection of 10 cubic centimeters of Dakin's was given with perhaps a little more force than usual. The patient suffered a sudden, sharp pain in the lower abdomen which continued for over an hour. An injection two hours later failed to return, indicating that the fluid was entering the free peritoneal cavity. The catheter was removed, all treatment stopped, and the patient made a speedy recovery.

Daily bacterial counts have been made in all the cases. While this is not an essential and while the scientific accuracy of the counts may be questioned, we have found them of some practical value. The drop from infinity of organisms usually corresponds closely with the stage of clinical cleanliness when drainage may safely be discontinued. The counts, therefore, aid in a nicer determination of the condition of the wound.

When possible the dressings are done just before a Dakin's injection is due and smears are made either from the deep ends of the wicks in the early dressings or from exudate pressed gently from the wound. Smears from the superficial wound during period of separation dressings have been made and recorded in several cases. These of course are of purely academic interest. Smears taken and recorded for long periods after suppuration had ceased, to determine possibility of safe secondary closure did not indicate that this procedure is feasible.

Treatment of wound after peak of infection has been passed. That secondary closure by suture in the average case is neither feasible nor safe has been a disappointment, but can be satisfactorily explained by the biologic and dynamic conditions present. An abdominal drainage tract represents a dead space, the walls of which as infection declines are lined by granulation tissue. These walls have a very decided tendency to collapse and obliterate the dead space. In the re-entrant angles of this

Fig. 6. Case having two drainage tracts (cæcal and pelvic). Arrangement of tubes at end of 48 hours. The closed tube to the pelvis has been removed and the fenestrated tube loosened and shortened. Trial injection by catheter seen entering end of tube has been made. The cæcal tube (one only) has been loosened and shortened and an instillation catheter introduced. Carrel tubes to superficial wound appear emerging from gauze compress.

collapsing cavity micro-organisms may remain in pockets. Sudden increases in the bacterial counts after negative counts for several days indicate the presence of these pockets. While it is theoretically possible that by continued injections of Dakin's fluid the infected cavity might eventually approach nearly enough a sterile condition to permit successful closure of the skin, the time element involved renders such attempts apparently futile. There is a great mass of clinical evidence to prove that residual abscesses rarely occur when drainage is discontinued after suppuration has declined and the wound appears clean. The injection of any fluid, antiseptic or otherwise, into the tract after healing has begun directly opposes the major factor of the healing tendency, i. e., collapse of the surrounding walls. The remaining factors in healing, the shrinkage of tissue and proliferation of new tissue are minor considerations.

In our last cases we removed the instillation catheters and Carrel tubes (if they still remained) just as soon as the wound ceased to show signs of suppuration and bright coral red granulations were in evidence, and applied a dry dressing. The bacterial counts in all these cases showed at this time few if any organisms. All of these cases left the hospital

before the twentieth day with wounds healed or with small granulating areas flush with skin surface.

The reader is referred to the case reports and bacteriological charts for detailed description of the technique used under varying conditions.

Tabulation of the 18 cases gives the following data: acute appendicitis with acute local peritonitis was the final diagnosis in 6 cases, *acute appendicitis with abscess in 11 cases*, and acute appendicitis with peritoneal abscess and acute diffuse peritonitis in 1 case.

Intermuscular incision was used in 8 cases, intermuscular with Weir extension in 7 cases, and right rectus incision with splitting of muscle in 3 cases.

The lesions of the appendix found were: acute inflammation with fibrin on surface in 4 cases; gangrenous appendix in 14 cases; perforation

Fig. 7. Same as Figure 6, with cæcal and pelvic tracts. The drainage tubes have been removed leaving No. 18 French catheters in the two tracts. One of the Carrel tubes has been forced out by rapid closure of the upper angle of the wound. Untied sutures may be seen knotted and strapped back.

of appendix had occurred in 7 cases. Thrombosis of the meso-appendix was noted in 1 case and gangrenous omentum in 1 case.

Free clear exudate was found in 1 case; free cloudy exudate without odor in 6 cases; free foul pus in 2 cases. Localized pus collections were present in 12 cases, in 3 of which the amount exceeded 100 cubic centimeters. Multiple pus pockets were present in 1 case. Foul pus at operation was found in 12 cases. The location of abscesses was as follows: pelvic, 5; subcæcal, 2; procæcal, 1; mesocæcal, 1; retrocæcal, 1; extraperitoneal, 3 (retrocolic, 2; retrocæcal, 1).

The appendix was removed completely in 16 cases, in 14 of which the stump was inverted and site re-inforced in 13 cases. In 2 cases the stump was crushed and tied off. In one case the appendix had sloughed off near its base and the necrosed portion which contained fæcaliths was alone removed.

Cultures were taken at operation in all cases. There were no sterile cultures reported. In 2 cases, however, final culture report was not recorded, but in each of these cases organisms were present on smears

taken at operation. In the 16 culture reports, bacillus coli communis was present 12 times; bacillus coli communior, 1; streptococcus hæmolyticus, 1; streptococcus non-hæmolyticus, 2; streptococcus viridans, 1; streptococcus not differentiated, 5; bacillus pyocyaneus, 1; gram negative bacilli, 2.

Double rubber tube drains were used in 11 cases, in one of the cases two sets being inserted and in 5 of the cases an additional single fenestrated tube was introduced. In 4 cases single rubber tubes were used, for the most part cases with abscesses near the operation wound. In 3 cases multiple single tubes were used. No cigarette drains were employed. Drains were placed to pelvis 13 times, to cæcal region 12 times, and to right lumbar gutter 2 times. All drains were introduced through the operative wound.

Closure of peritoneum in a manner to preclude continued contamination of the wound from peritoneal exudate was undertaken in 16 cases. Separation type of dressings was applied in these cases. The only cases in which this part of the technique was not employed were the first case of the series and one case in which particularly free drainage was thought desirable because of the widespread infection present.

Skin closure was loose in 17 cases. We had cause to regret the snug closure in the remaining case. The aponeurosis of the external oblique was included in the skin suture in 3 cases, 2 of which were ill advised. The one case in which the procedure was perhaps justified was one with a long right rectus incision and with marked distention of intestines. Untied sutures were placed in skin near the center of the wound in 4 cases.

Carrel tubes were placed along the aponeurosis in all cases.

RÉSUMÉ OF POSTOPERATIVE WOUND TREATMENT

Early replacement by smaller drains, or removal of the closed tube arm was carried out in all cases, the average time for this manœuver being 2.6 days.

The average time at which instillation catheters alone were present in the drainage tract was 4.5 days.

Of the 27 tracts present in these 18 cases, all but 4 were treated by Dakin's fluid. Two of these were tortuous and in 2 the drains were removed early without replacement.

Dakin's fluid was used on an average of 9 days in the superficial wounds, the average amount being 10 cubic centimeters every two hours.

The average time at which Dakin's was first introduced into the deep drainage tract was 2.7 days (65 hours) from time of operation. The average time when Dakinization of the deep tracts was discontinued was 13.6 days after operation. The average duration of the deep antiseptic injections was, therefore, 11.2 days. The amounts of Dakin's fluid used varied from 2 to 10 cubic centimeters. In all cases except the first 2, full strength Dakin's was used and 5 to 10 cubic centimeters in each tract was the customary amount.

Antiseptic treatment of the deep tracts was abruptly discontinued because of complication in 3 cases: the first (Case 3) on the tenth day because of indications of residual abscess; the second (Case 7) because of mechanical ileus; the third (Case 9) because of accident to drainage tract during injection on the thirteenth day. *Vide supra.*

Five per cent dichloramine-T was used at operation and during the first 48 hours in 15 of the cases.

There was evidence of insufficient drainage in but one case (Case 3). On the tenth day signs and symptoms of residual abscess developed. Dakin's injections were discontinued. Measures to relieve condition were unnecessary as the wound shortly spontaneously discharged a quantity of exudate.

The re-institution of drainage was not necessary in any of the cases nor were measures to improve drainage necessary.

The average time when all treatment was stopped and dry dressings applied was 13.8 days.

There was no gross suppuration present in one case, slight suppuration in 5, moderate suppuration in 7, and profuse in 5.

The discharge was odorless throughout in 2 cases. The average duration of odoriferous discharge in 15 cases was only 6 days, and in a number of cases the odor was slight.

Seven cases passed through their period of drainage without apparent slough; in 8 cases the slough was superficial or from the deep tract (abscess wall); in 3 cases only was there definite slough of aponeurosis, and in 2 of these the slough was what would ordinarily be considered slight. The one case in which the aponeurosis suffered considerable damage was Case 7. In this case the aponeurosis was included in the skin sutures and Dakinization of the superficial wound was thereby rendered inefficient.

There were no cases of disruption of the wound, and but one (Case 7) in which real wound infection occurred. In no case did the intestine herniate into the wound.

Bacterial counts ranged below 60 per field throughout in 4 cases. In 13 cases the counts remained at infinity until the eighth day (average) when a drop in the number of bacteria occurred. The earliest drop from infinity was the third day and the latest drop the twelfth day. The drop was rapid and abrupt in some cases and slow in others.

The average time when suppuration ceased and wounds were entirely free of slough and lined by bright red granulations, with bacterial counts low was 10.9 days (16 cases treated throughout by antiseptics). The 2 cases excluded are Case 7, with mechanical ileus interrupting treatment on sixth day, and Case 12, death on fourth day.

Closure of wound by suture was attempted in 5 cases with 3 successes and 2 failures. Gradual closure aided by strapping with adhesive has been the rule, and has proved the most safe and practical method in our hands.

Certain complications were in a way anticipated, as we were proceeding in an untried field. While the early introduction of Dakin's fluid in the local peritoneal infections of the dog gave us a certain degree of assurance, the reaction of the human peritoneum was an unknown factor that could only be determined by careful trial. That Dakin's fluid did not destroy protective adhesions, that suture material imbedded in tissue was not acted upon in any serious manner, that secondary hæmorrhage and fistula did not result from its use was very soon established. In these 18 cases there has not been a single case of secondary hæmorrhage or fæcal fistula. There has been but one residual abscess which emptied itself spontaneously through the drainage tract.

The only serious complication of the series was a mechanical ileus, which was probably due to tube pressure. In this case a single tube of unusually large lumen and very thin wall was placed to the pelvic abscess. The end of the tube was not properly beveled, and to prevent possible buckling the lumen was filled out with more gauze than is advisable. At operation on the sixth day an angulated loop was found in the pelvis in a position indicating possible pressure from the drainage tube. The condition of the tract was found unusually clean for the sixth day and the case made an uninterrupted recovery. Dakin's was not used after the operation for relief of ileus and there was considerable wound suppuration, resulting in a ventral hernia.

There were two pulmonary complications, one an acute bronchitis, the other a probable pulmonary embolism occurring in the one fatal case. The patient (Case 12) was a very obese woman, age 50, with a gangrenous perforated appendix; free foul pus in poorly localized collections through lower right abdomen; visceral peritoneum covered by thick, fibrinopurulent exudate. The omentum, fully 5 centimeters in thickness, was acutely inflamed. That her resistance was unusually low was indicated by a low leucocyte reaction after more than 48 hours of infection. (White blood cells 7,400, polymorphonuclears 78 per cent.) Following operation her abdominal condition was apparently improving, when on the fourth day she became dyspnœic, cyanotic, face flushed, and heart action irregular. Her cough was unproductive. Fine moist crepitant râles were heard at both bases. Death occurred 102 hours after operation. Unfortunately no autopsy was obtained. In this case separation dressings were not employed. Dakin's fluid was introduced in the deep tracts after 48 hours, with free return and no pain reaction.

The condition of wounds on discharge was as follows:

Healed 2 cases; healed with clean crust 2; small granulating areas flush with skin surface 6; large granulating area (0.5 by 2 centimeters) 1; with shallow sinus 6. There was only one case discharged with a weak wall (Case 7, Dakin's treatment interrupted by development of mechanical ileus).

The average duration of hospital stay was 24.1 days. During the developmental period of the technique, several cases were Dakinized for longer periods than routine practice would demand.

Sixteen of the 17 recovered cases have been followed up over a period of 2 to 6 months. There have been no symptomatic failures indicating untoward late peritoneal changes (adhesions) and no economic failures. Unfortunately the exact time of resuming work or play has been recorded in but 3 cases. One of these was a child who resumed full play on reaching home, the other 2 resumed work at the end of 3 weeks after leaving hospital. The anatomical results were excellent in 12 cases (75 per cent); there was a slight bulge present in one case (rectus incision) at 6 months and a diffuse bulge at 2 months in the child referred to above; there were 2 hernias (12.5 per cent), one small and one large, the latter occurring in case not Dakinized throughout.

There have been no late secondary complications or operations.

While 18 cases represent a small series it comprises infections of fully average severity and the results show a decided improvement in many respects over those attained under simple drainage treatment, when com-

TABLE I

	263 cases reviewed	Best results attained under methods of simple drainage			Antiseptic treatment, author's 18 cases
		A_1 (32 cases)	B_2 (128 cases)	C_3 (20 cases)	
Period of suppuration	15.1 days	14.5 days	15.6 days	13.8 days	10.9 days
Immediate secondary procedures (to improve drainage, etc.)	16.4 per cent	3.3 per cent	19 per cent	20 per cent	5.5 per cent
Fæcal fistula	7.5 per cent	10 per cent	0 per cent	6.9 per cent†	0 per cent
Duration of hospital stay (initial)	26.5 days	22.7 days	23.4 days	20.9 days†	24.1 days
Perfect anatomic, symptomatic, economic results	58 per cent—*	53.4 per cent	57.1 per cent	63.7 per cent	75 per cent
Weak walls					
Bulges	18% } 38%	20% } 40.6%	14.3% } 42.9%	22. % } 36.3%	12.5% } 25%
Herniæ	20% }	20.6% }	28.6% }	13.6% }	12.5% }
Deaths	0.1 per cent	3.3 per cent	3.6 per cent	3.4 per cent	5.5 per cent

A_1—Cases were treated by cigarette drains, late removal, few irrigations.
B_2—Cases were treated by early replacement of tube drains by catheter and daily irrigation.
C_3—Cases were treated by early loosening and shortening of tube drains, with irrigation, late replacement of drains by smaller tubes.
*In 4 per cent condition of abdominal wall could not be determined from the records.
†There were 5 secondary procedures in one case, making total unusually high; 2 fæcal fistulæ in 1 case; one case remained in hospital 205 days. Average duration of hospital stay with this case excluded-23.2 days.

parison is made either with the 263 cases reviewed[1] as a whole or the cases handled by any one of the various methods employed by individual operators (Table I).

Dakin's fluid and dichloramine-T solution have been used by several surgeons at the Presbyterian Hospital in the treatment of their cases during the past few months. In this early period of the use of antiseptics intra-abdominally we have all endeavored by various means to render the method of their use as simple as possible. The author is indebted for many valuable suggestions to the experience of other members of the staff who have employed Dakin's fluid in the treatment of their cases. A review of the 13 other cases of appendicitis in which antiseptics were employed shows no serious complication attributable to the method. Fæcal fistula occurred in 2 cases, one thought to be due to prolonged pressure of the drainage tube; the other occurred at the twentieth day. Hæmorrhage occurred from a right rectus wound in one case. Two secondary abscesses developed, one mural and one peritoneal. There was one death. The average duration of hospital stay was 24.1 days. As most of the cases have been recent ones the follow-up results are incomplete.

The following observations have been made in the cases treated by others when favorable expectations were not being realized:

1. That Dakin's fluid was not begun in the superficial wound until the third or fourth day.

2. That insufficient amounts of Dakin's fluid were used (1 to 2 cubic centimeters) both superficial and deep.

3. That injections have been given at infrequent intervals, every 3 to 4 hours, or discontinued entirely while patient was sleeping.

4. That drainage tubes have been left *in situ* for 5 to 7 days and Dakin's fluid given only within the tubes, allowing little or no contact of antiseptic with wall of tract.

5. That Carrel tubes for protection of aponeurosis have been improperly placed:

a. Wound sutured too tightly about these tubes, making injection difficult and forcible injection causing dissecting up of the loose tissues.

[1] Drainage in appendicitis. Ann. Surg., 1919, Dec.

b. Tubes introduced from the angles of the wound rather than the center, with gaping of wound resulting after a few days.

While unremitting care and attention to essential details are absolutely necessary in the antiseptic treatment of these cases, it is the author's conclusion that Dakin's fluid may be used with safety and with far better immediate and probably better remote results than may be attained by simple drainage.

While it is not within the scope of this report to enter into a discussion of the exact manner in which a 0.5 per cent neutral sodium hypochlorite solution may act as an antiseptic, certain clinical observations and perhaps speculations may be of interest. It does not seem too much to hope that with the proper introduction in adequate amounts of this or some other antiseptic the vitally important tissues of the abdominal wall may be completely preserved in all cases by preventing the stage of contamination from passing to one of infection. This, in the author's opinion, is the major part of our problem. The abdominal drainage tract in these cases within 48 to 72 hours represents a limited infected dead space, the walls of which are lined by fibrin, leucocytes (dead and living), and bacteria. The structure of the walls of the tract is in all cases a delicate on and as the coils of intestine may be united by minimal adhesions, gentle treatment is entirely essential if antiseptics are to be introduced. The tensile strength of the drainage tract as treatment continues, probably decreases rather than increases. The introduction of an antiseptic having the known irritant properties of Dakin's fluid within the general abdominal cavity must always be done under low pressure and with certain and unimpeded return into the wound dressings. While the degree of infection in the dead space of the drainage tract must increase rapidly during the first 48 to 60 hours after operation, delay of introduction of this antiseptic during this period seems necessary from the viewpoint of safety. During this period when adequate antiseptic treatment of the deep tracts seems precluded the discharge of pus into dressings not in contact with the wound and the attempt to minimize the infectivity of the issuing exudate by dichloramine-T strips within the drainage tube seems the most rational and safe procedure. An antiseptic necessarily must have actual contact with infected tissue in adequate quantity, and this may be accomplished 48 to 60 hours after operation by removal of one or both tubes, the fluid being introduced by catheter, placed to the depth of the tract. Just what Dakin's fluid introduced in 10 cubic centimeter amounts into these tracts accomplishes may be debated from many angles. A thorough mechanical flushing of the tract with fluid during the period of active infection may be credited with at least removing the detachable products of infection. We know that the infected fibrin lining the walls of the dead space eventually comes away in fragments or extensive sloughs, leaving the wall lined by clean granulation tissue. It has been claimed that Dakin's fluid causes a rapid disintegration of necrotic tissue. Our experience has been unqualifiedly in favor of this assertion, certain of the cases with definite necrotic abscess wall at operation healing without the discharge of macroscopic slough. Whether Dakin's fluid is actively germicidal, whether by its slight irritant nature more phagocytes are attracted to the infected locality, are questions of interest but rather indeterminable in a clinical

study. Whether the action of the antiseptic in killing bacteria outweighs its destructive action on phagocytes, or whether the favorable outcome of wounds treated by Dakin's fluid is brought about despite the antiseptic rather than by reason of any inherent virtue are academic questions. Some investigators give the credit to the bactericidal influence of the antiseptic; others to the phagocytic activity which goes on during the intervals between the injections. Whatever may be the action of the Dakin's fluid, our results seem to indicate that, with continued flushing with 5 to 10 cubic centimeter amounts at 2 hourly intervals, these tracts cease to discharge pus and are lined by a clean granulating wall at an earlier period in the average case than when treated otherwise. When the period of suppuration has passed, the biologic-dynamic considerations of a clean dead space seem to favor immediate cessation of all treatment in order that wound healing may be most favored. Partial secondary suture (suture of the angles of the wounds) may aid in hastening closure; complete secondary closure will probably be disappointing.

There is one consideration which may be of greater importance than has been generally realized, namely the influence of the infection curve in the less resistant tissues of the abdominal wall upon the curve of infection in the tract lined by highly resistant peritoneum. It is conceivable that the rather large group of cases that surgeons drain when in doubt have their course greatly protracted by retrograde infection from the superficial portion of the wound. All dressing procedures, loosening, or removal and replacement of drains favor this contamination of the deep tract. Thorough antisepsis of the superficial wound with care in replacement of drains within the lumen of existing drains is well worthy of attention, whether or not one wishes to accept the responsibility of introducing an antiseptic into the intra-abdominal drainage tract.

In conclusion emphasis should again be laid upon the necessity of thoroughly mastering the details as well as the principles underlying the introduction of such antiseptics as Dakin's fluid into deep, infected abdominal drainage tracts. While a single accidental admission of 5 to 10 cubic centimeters of Dakin's fluid through an infected tract into the free peritoneal cavity would probably not result fatally, it would certainly be productive of intense pain and alarming symptoms. We believe that the probability of such a complication is slight if the treatment is carried out along some such precautionary lines as have been found safe in our cases. If one is not willing to give the time necessary to gain a correct theoretical understanding, and is not willing to give the cases his careful, personal attention at daily dressing, the method should not be employed as it will probably not only prove disappointing, but may result in serious complications.

Case Reports

Case 1. A. C. History No. 37300. Italian, male, age 32. Admitted February 10, 1918. Discharged February 24, 1918.

History of present attack. Onset of pain in epigastrium 52 hours before admission, localizing with acute tenderness in right lower quadrant after 24 hours; repeated vomiting throughout duration of illness.

Physical examination on admission. Abdominal examination: Definite right rectus rigidity; general abdominal tenderness, most decided 1 inch below McBur-

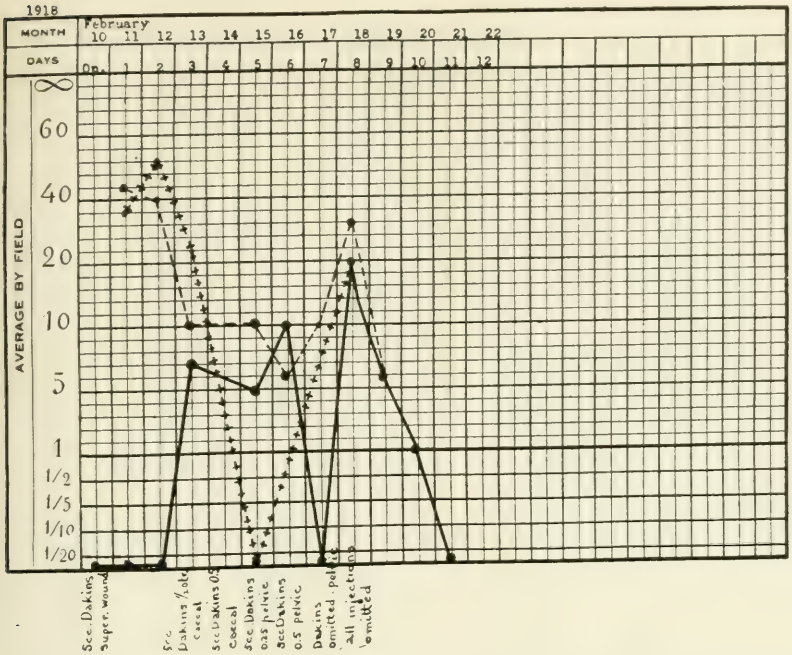

Chart 1. A. C., Ward 10, History No. 37,300. Acute appendicitis with acute local peritonitis. Gangrene of appendix and omentum. ——— Superficial. – – – – Cæcal. ++++ Pelvic.

ney's point. Temperature 102.4°; pulse, 90; respiration 24. Leucocyte count 21,100. Polymorphonuclears 66 per cent.

Findings at operation. Free fluid present in considerable amount; that issuing from pelvis turbid but odorless. Appendix gangrenous throughout, and omentum adherent about appendix was greatly thickened, indurated and appeared likewise necrotic. Mesentery of appendix infiltrated, friable; cæcal wall indurated.

Procedure. Oblique intermuscular incision; Weir extension. Necrotic appearing mass of omentum excised; appendix amputated and stump inverted. Reinforcing suture taken bringing free edge of omentum over site of inversion. Double soft rubber tube drain containing gauze in one arm placed to cæcal region and a single tube to depth of pelvis. Peritoneum closed tightly about drainage tubes; deep muscle planes loosely drawn together with interrupted plain catgut and external oblique and skin sutured only at angles. Silkworm-gut sutures placed in remaining central portion of wound but left untied. Two Carrel tubes placed in superficial wound. Gauze packing introduced in angles between drainage tubes to close communication between wound and peritoneal cavity.

Pathological Report No. 20808. Gross: (1) Specimen is an appendix, 4½ centimeters by 1.2 centimeters which is swollen, greyish green in color, and is soft and covered in places with fibrinous exudate. On section it shows partial obliteration of the coats by infiltration by blood and pus. The lumen is filled with a thick semisolid whitish material. (2) An oval mass of œdematous infiltrated fat which is 6 by 4 centimeters. It is partly covered by a thick whitish layer of fibrin varying from 1 to 4 millimeters in thickness. On cross section the mass appears hæmorrhagic.

Microscopic. (1) The mucous membrane of the appendix is completely gone and its place taken by a thick layer of granulation tissue which is exceedingly œdematous and infiltrated with countless leucocytes. The other coats are barely distinguishable; in places they are completely necrotic; everywhere there are countless leucocytes, interstitial hæmorrhages, much fibrinous exudate, and some of the blood vessels are thrombosed. (2) The omental fat is infiltrated everywhere with leucocytes, shows a marked proliferation of fibroblasts between the groups of fat cells,

and extensive extravasations of blood. On the surface is a thick, laminated mass of fibrin filled with many leucocytes but practically free from red blood cells.

Bacteriological report. Exudate from pelvis: Smear: Gram positive coccus. Gram negative bacillus. Culture: Streptococcus. Gram negative bacillus.

Injections of sodium hypochlorite solution 0.25 to 0.5 per cent. Five cubic centimeters of 0.5 per cent sodium hypochlorite injected through the two tubes in superficial wounds every two hours, beginning at the time the patient left table.

Third day following operation. Wound showed small amount of slimy yellowish exudate in depth; packing removed from tube to cæcal region was saturated with reddish brown pus having slight colon odor; packing from pelvic tube saturated with light yellow exudate. Double tube to cæcum removed and replaced by single fenestrated tube of same size, containing a small instillation tube with strip of gauze packing. Intraperitoneal injection of 0.25 per cent sodium hypochlorite warmed to 100°F. Five cubic centimeters every 2 hours begun in cæcal tract only; pelvic tube not being disturbed.

Fourth day. The strength of intraperitoneal injection increased to 0.5 per cent; pelvic tube shortened 2 centimeters.

Fifth day. Wound shows no gross evidence of suppuration; packing from pelvic tube saturated with yellowish exudate which appears more purulent in character, though odorless. Instillation tube introduced through pelvic drainage tube, the latter being then withdrawn and 5 cubic centimeters, 0.25 per cent sodium hypochlorite injection begun. Silkworm sutures at angles tied; no irritation present about sutures.

Sixth day. Drainage tube removed from cæcal tract, leaving instillation tube *in situ.* 0.5 per cent sodium hypochlorite now injected in both tracts.

Seventh day. Instillation tube in pelvic tract removed; injections discontinued. Small stain of exudate in dressings having chemical odor. Remaining suture in center of wound tied. One small instillation tube remains in cæcal tract.

Eighth day. Remaining tube removed; dry dressing. There is no wound tenderness; slight reddening about stitch holes.

Twelfth day. Remaining sutures removed; no exudate on dressings.

Fourteenth day. Wound entirely healed; abdominal wall appears to be firm. Scar present as a narrow red line.

Follow-up notes. 3 months: General condition excellent; scar slightly raised and cord-like; abdominal musculature firm.

Case 2. J. F. History No. 37599. Italian, female, age 25. Admitted March 14, 1918. Discharged April 5, 1918.

History of present attack. Onset of pain in lower abdomen 7 days before admission, localizing with acute tenderness in right lower quadrant. Has been constipated during illness; no nausea or vomiting.

Physical examination on admission. Palpable small tender mass in right lower quadrant; right rectus muscle on guard. Vaginal examination painful on palpation of right fornix. Temperature, 100.2°, pulse 90. Leucocyte count 15,600. Polymorphonuclears 85 per cent.

Findings at operation. Small amount of cloudy yellowish, odorless peritoneal exudate. Appendix was retrocæcal with exception of tip which was free and pointing inferiorly; appendix was kinked upon itself, the middle third being retroperitoneal. The mesenteriolum was short, attached only to proximal third, very œdematous and friable. Appendix was acutely inflamed throughout.

Procedure. Oblique intermuscular incision; appendix removed by subserous dissection in its middle third and in so doing lumen was penetrated and several small foul fæcal particles escaped. Stump of appendix inverted by pursestring of Pagenstecker. No reinforcing sutures taken because of œdema of cæcal wall. Soft rubber, fenestrated drainage tube (6 millimeters lumen) containing gauze packing introduced to cæcal region and peritoneum closed tightly about it. Internal oblique and transversalis planes sutured rather loosely about tube, and external oblique united at either angle. Silkworm sutures placed through skin and subcutaneous tissue, the angle sutures alone being tied. One Carrel tube placed in superficial wound.

Wound dressings. Layer of absorbent gauze in contact with skin, the drainage tube being allowed to project through this layer and through a layer of non-absorbent cotton to discharge into another layer of absorbent gauze the rationale

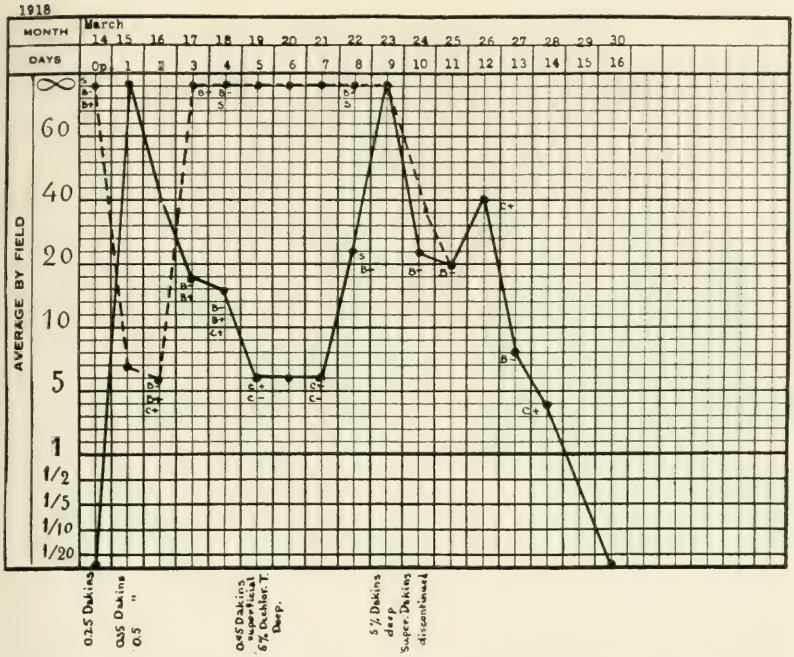

Chart 2. J. F., Ward 8, History No. 37,599. Acute appendicitis with acute local peritonitis. ——— Superficial. – – – – Cæcal.

being the isolation of the wound in abdominal wall from contamination of intraperitoneal discharge.

Pathological Report No. 20948. Gross. Specimen consists of an appendix 7 centimeters long, with a distinctly bulbous tip which is 1½ centimeters in diameter while the remainder of the appendix is ½ centimeter in diameter. Over the whole narrow part the serous and muscular coats appear to have been stripped off. It is here and there discolored brown and black and there are definite adhesions seen along the mesenteric portion. The wall is thickened, the lumen filled and there is a medium sized soft fæcalith probably from the tip.

Microscopic examination. The subserosa is very much thickened, containing extravasated blood; some necrosis of the surface, evidence of œdema and marked infiltration with round and eosinophile cells. Except for diminished lymphoid tissue, the picture is the same throughout all the coats. The lumen is empty and the mucosa intact. Polymorphonuclear neutrophiles are seen with the eosinophiles, particularly in the subserous layer which is greatly thickened by œdema and proliferation of fibroblasts and extravasated red blood cells.

Bacteriological report. Culture of peritoneal exudate: bacillus coli communis.

Postoperative care of wound. Injections of sodium hypochlorite solution 0.25 to 0.5 per cent superficial; deep after eighth day. Five per cent dichloramine-T in chloracozane deep, from fifth to ninth days.

Fourth day. 0.25 per cent sodium hypochlorite injected into superficial wound in 5 cubic centimeters amounts every two hours for first two days, then 0.5 per cent solution used. Gauze packing has been removed from drainage tube daily and replaced by fresh plain gauze. There has been no apparent suppuration. The gauze from tube has shown only a light yellow stain. The smears taken from deep end of gauze, however, have shown an increasing bacterial count; smears of superficial wound have shown decreasing count since 0.5 per cent solution has been used.

Fifth day. Gauze packing from drainage tube saturated with brownish colon smelling pus. 5 per cent dichloramine-T introduced to depth of drainage tube on gauze. 8 cubic centimeters, 0.5 per cent sodium hypochlorite solution injected into superficial wound.

Sixth day. Superficial wound lined by clean granulations. There has been some escape of colon pus about drainage tube into superficial wound. Tube removed and replaced by smaller tube containing the dichloramine-T gauze. Sodium hypochlorite injections continued superficially.

Ninth day. Treatment has been continued dichloramine-T being used as packing within drainage tube and sodium hypochlorite superficially. There has been a fresh discharge of brownish to greyish pus with strong colon odor, containing infinity of organisms; small patches of slough have separated. Sutures at angles have been removed and those near center of wound tied; no reaction about sutures. No. 16 French soft rubber catheter introduced to depth of drainage tract and 5 cubic centimeters sodium hypochlorite solution injected every 2 hours; superficial Carrel tube removed.

Eleventh day. Intraperitoneal injections have been continued during past 48 hours; there is moderate amount of light grey exudate having chemical odor only. Bacterial count has dropped from infinity to 22 per field.

Fifteenth day. Exudate has lessened daily; at present small amount, slimy, clear. Bacterial count, 4 per field. Injections discontinued and remaining suture tied.

Seventeenth day. Suture removed; wound presents narrow line, granulation in center of wound.

Follow-up note. 3 months: scar 2 to 4 millimeters wide, pink. Abdominal musculature firm throughout. 8 months: general condition excellent; abdominal wall firm.

Case 3. H. B. History No. 37744. American, female, age 10. Admitted March 28, 1918. Discharged April 28, 1918.

History of present attack. Onset of general abdominal pain, 3½ days before admission. Pain at first was associated with vomiting. After 24 hours there was localization of pain with tenderness in right lower abdomen; this remained dull, constant, non-radiating. Bowels moved day before admission.

Physical examination on admission. Abdomen shows slight general distention, slightly more prominent in right lower portion; it is held almost motionless during respiration. There is acute tenderness and rigidity over wide area, comprising entire right lower abdomen and sense of mass is appreciated. Temperature 101°. Pulse 134. Leucocyte count 23,800. Polymorphonuclears 93 per cent.

Findings at operation. Moderate amount of free thin, reddish exudate; poorly walled in collection subcæcal in position with two or three extensions toward mid-line containing 50-60 cubic centimeters gray pus, having foul colon odor. The wall of inferior layer of the mesentery and adjoining surfaces of cæcum, parietal wall and coils of small intestine. One loop of small intestine lying between main abscess cavity and a pocket toward mid-line presented a green, lusterless, gangrenous appearance. The appendix was retrocæcal, doubled upon itself so that tip ended about 2 centimeters inferior to cæcum. Appendix was acutely inflamed, wall œdematous, surface covered with fibrinopurulent exudate and a perforation at tip, 2 to 3 millimeters in diameter.

Procedure. Oblique intermuscular incision, Weir extension. Appendix removed, stump inverted with purse-string of Pagenstecker and reinforcing Lembert sutures of plain gut. Pus removed from abscess cavity by suction and sponging, extensions of pus between coils toward mid-line and pelvis being followed up. Soft rubber drainage tubes, with 3 millimeters punched fenestrations placed about 1.5 centimeters apart, and containing plain gauze packing placed to main abscess cavity and to mid-line pelvic position. Wound closed as in Case 2. Two Carrel tubes placed in superficial wound. Wound dressing as in Case 2.

Pathological Report No. 21012. Gross. Specimen consists of an appendix, 5 by 1.3 centimeters which is swollen, reddened, and covered with a thick layer of fibrin and presenting near the tip a perforation which is 3 millimeters in diameter, filled with granulation tissue. On section it is seen that the perforation communicates directly with the lumen.

Microscopic examination. Section of appendix in region of perforation shows the mucous membrane has rolled out through the perforated area to the external surface. The extremities of the muscularis are covered with a thick layer of granulation tissue and on the surface of this there is a thick mass of fibrin filled with leucocytes which extends all the way around over the serous surface of the ap-

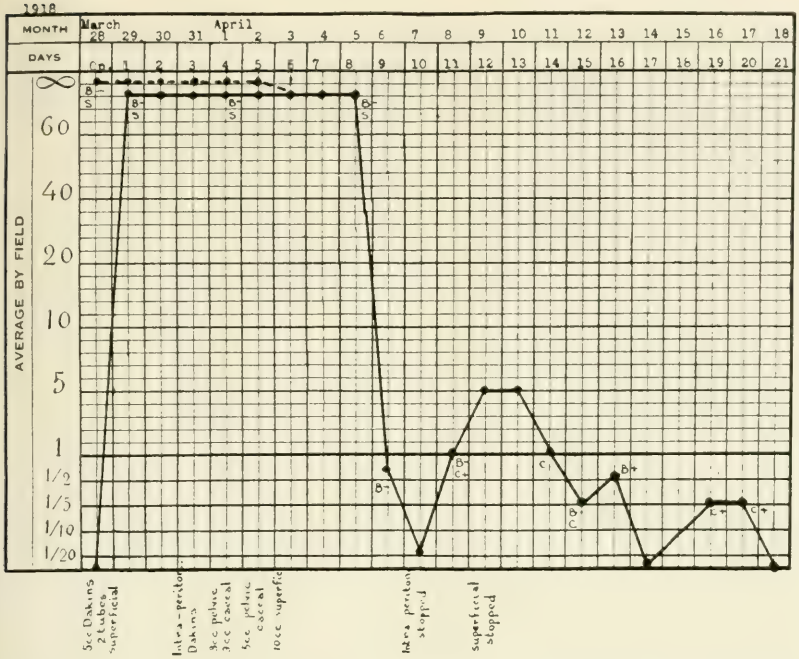

Chart 3. H. B., Ward 8, History No. 37,744. Acute appendicitis with peritoneal abscess, subcæcal, pelvic; and acute local peritonitis. ——— Superficial. – – – – Cæcal and pelvic tracts.

pendix. In the lumen the mucous membrane is intact. The submucosa, subserosa, and muscularis are œdematous and infiltrated with leucocytes.

Bacteriological report. Culture peritoneal exudate: streptococcus hæmolyticus, bacillus coli communis.

Postoperative wound treatment. Third day. There has been a profuse discharge through drainage tubes of dark brown pus having fæcal odor. This has been collected in superficial gauze layer. The wound, in spite of instillations of 0.5 per cent sodium hypochlorite in 5 cubic centimeters amounts through two tubes every two hours, has become lined by a dark slough. Plain gauze strips placed in angles between drainage tubes at the peritoneal level have apparently not proved efficient in isolating the superficial wound from the intraperitoneal exudate. No. 12 French catheters introduced to depth of drainage tracts within the tubes and 3 cubic centimeters of 0.5 per cent sodium hypochlorite solution injected every two hours.

Fifth day. No. 18 French catheters introduced and drainage tubes removed; one Carrel tube left in superficial wound. Skin about wound appears red and tender and stitch holes show signs of infection. Five cubic centimeters sodium hypochlorite injected through each tube intraperitoneally and 10 cubic centimeters through superficial tube every 2 hours.

Seventh day. Discharge is light grey in color and losing its colon odor: superficial wound now presents clean granulating surface, the slough having disappeared. No macroscopic evidence of slough has been noted on dressings.

Ninth day. For past three days patient's temperature has been maintained at a higher level, 101 to 102°. Leucocyte count, 22,400. Polymorphonuclears 88 per cent. There is a moderate tenderness to median side of wound but no mass palpable either abdominally or rectally.

Tenth day. Profuse reddish brown discharge containing slimy mucus-like flakes and having no distinctive odor present on dressings. Temperature has dropped, abdomen is less tender and leucocyte count now 18,500, polymorphonuclears 80 per cent. Intraperitoneal injections stopped because of possible fistula. Bacterial smears of this discharge showed no organisms; the collection had very

likely been accumulating as a result of the repeated injections into the wide abscess spaces. The superficial tube left in place and 5 cubic centimeters of the solution injected as before.

Twelfth day. Bacterial counts have been less than one per field for past three days. Solution discontinued, remaining sutures tied, rubber tissue drain left to level of peritoneum.

Fifteenth day. There is a considerable induration about stitch holes; sutures removed and wound strapped. There continues to be a slight discharge of odorless, whitish exudate. Drains discontinued.

Twenty-first day. Slight discharge continues; wound presents clean granulating surface over which epithelization is slowly taking place.

Thirtieth day. Patient discharged with wound showing granulating area, 4 millimeters by 2 centimeters. A slight serous discharge still present from a sinus which admits a probe 1.5 centimeters. Abdominal wall is apparently firm; no impulse on coughing.

Follow-up note. 2 months: general condition excellent; no symptoms. Scar, wide flat; wall thin but firm. 5 months: there is a small hernia in center of wound; hernial neck admits tip of index finger.

Case 4. H. S. History No. 37944. German, female, age 33. Admitted April 18, 1918. Discharged May 9, 1918.

History of present attack. Onset of epigastric pain 3 days previous to admission. Pain localized to right lower quadrant after 24 hours. Vomiting was repeated during the second 24 hours of attack. Pain more and more severe up to hour of admission.

Physical examination. Abdomen is tense in all areas; even to point of actual rigidity. Two areas of tenderness present; the greater 1 inch below and to inner side of McBurney's point; the lesser in the extreme epigastric notch. There is very definite rigidity in right lower quadrant; rebound tenderness present over entire abdomen. Temperature 100.6°. Pulse 80. Leucocytes 15,000. Polymorphonuclears 84 per cent.

Findings at operation. On opening peritoneal cavity there was an escape of considerable amount of cloudy, grey fluid having definite colon odor. The pelvis and lumbar gutter were filled with this exudate. Appendix was gangrenous from a point 1 centimeter from base to the tip and lay toward the mid-line adherent to anterior wall and surrounded by omentum. Surface of appendix was dark, bluish red, covered with patches of fibrin; the wall was softened in consistency; cæcum was somewhat indurated.

Procedure. Intermuscular incision; appendix amputated; stump inverted; pursestring of Pagenstecker with reinforcing plain gut suture in wall of cæcum. Exudate removed by suction and sponging; and punched soft rubber drainage tubes containing gauze packing placed to depth of pelvis and along bed of appendix. Tubes have a 7 millimeter lumen, 1.5 millimeter wall with 3 millimeter fenestrations placed 1 centimeter apart.

Closure. Peritoneum together with transversalis plane closed tightly about drainage tubes with plain gut. Angles formed by contacting drainage tubes packed with gauze strips, the ends lying on skin surface. Internal oblique and aponeurosis sutured loosely with plain gut and angles of skin approximated by interrupted silkworm gut. Two Carrel tubes placed in superficial wound, lying on surface external oblique. Dressings arranged as in preceding case.

Pathological report No. 21118. Gross. Specimen is an appendix, 7 centimeters long, which appears gangrenous to within 1 centimeter of its base. The maximum diameter is in the middle third, measuring 1½ centimeters. The surface is discolored and covered with thick areas of fibrinous deposit. The peritoneum has lost its smooth, shiny appearance. The mesentery is attached throughout its extent and measures 1½ centimeters opposite the middle third of the appendix. The mesentery is œdematous and infiltrated with fat. The appendix fluctuates and no perforation can be made out. Within the lumen is an enterolith, 8 millimeters in width and 1½ centimeters in length. The lumen is filled elsewhere with a thick reddish brown pus. The wall is thinned out measuring 1½ millimeters opposite the position of the enterolith. The lumen at this point is 1 centimeter.

Microscopic. Sections taken at different levels show a complete destruction of the mucosa and submucosa. No lymphoid element is present. The remaining

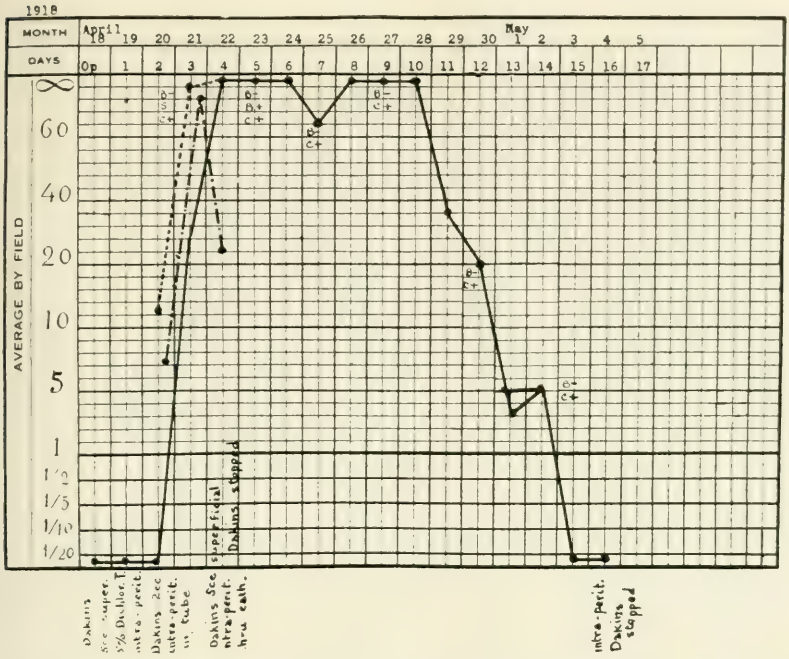

Chart 4. H. S., Ward 8, History No. 37,944. Acute appendicitis with acute local peritonitis. Gangrene of appendix; free, foul exudate. One drainage tract not treated. ——— Superficial. – – – – Appendix site. –.–.–.– Pelvic.

coats are heavily infiltrated with polynuclear leucocytes. The cellular elements are widely separated by the infiltrating cells and by œdema. There is a deposit of fibrin upon the peritoneal surface.

Bacteriological report. Culture peritoneal exudate: bacillus coli communis.

Postoperative wound treatment. Sodium hypochlorite solution injected into superficial wound in 5 cubic centimeters amounts through each tube every 2 hours from time of operation, continued until fourth day. 5 per cent dichloramine-T solution introduced to depth of both drainage tubes at end of 18 hours and sodium hypochlorite solution injections begun at end of 40 hours to depth of tubes in 2 cubic centimeter amounts.

Fourth day. During first 24 hours there was a profuse discharge of exudate from peritoneal cavity. For past 2 days discharge has been slight but has disagreeable odor. Gauze packing placed in angles between tubes removed today. No. 18 fenestrated soft rubber catheter introduced to depth of pelvic drain which was then removed. Owing to a buckling of the tube placed to site of appendix, catheter could not be similarly placed in this tract. Following removal of this drain, catheter was r placed by use of curved stylet, but trial injection with saline solution demonstrated faulty return so that sodium hypochlorite injections were not attempted in this tract.

Sixth day. Sodium hypochlorite solution to depth of pelvic tract increased to 5 cubic centimeters yesterday. Patient experiences slight cramping for a few minutes following these injections; solution ordered warmed to 100° F. with immediate cessation of this reaction. There is a moderate amount of brownish faintly colon smelling pus on dressings. Interior of wound appears clean. Sutures removed and angles strapped with adhesive.

Eighth day. Exudate moderate in amount, grey in color, having distinct colon odor. Ten cubic centimeters sodium hypochlorite 0.5 per cent strength injected and return collected and immediately titrated—.089 per cent. A second injection of 10 cubic centimeters collected and titrated—.119 per cent.

Thirteenth day. Injection to depth of the 12 centimeters pelvic tract have been continued. Today two ragged bits of slough about 7 millimeters in diameter were

present on dressings, probably issuing from the mesial tract which has not been treated with solution. Michel clips applied to approximate skin edges, except at point of emergence of catheter.

Sixteenth day. Smears showing no organisms; injections omitted. There is now a narrow sinus 6 centimeters deep.

Eighteenth day. Wound has closed, small crust at site of drainage.

Follow-up notes. 2 months: general condition excellent; scar narrow, pink line with slight retraction at site of drainage; abdominal wall firm. 6 months: condition the same.

Case 5. J. L. History No. 37983. American, male. Age 33. Admitted April 23, 1918. Discharged May 19, 1918.

History of present attack. Onset of pain was sudden, during sleep, 60 hours before admission; at first in epigastrium, later in right flank. Vomiting occurred a few minutes after onset of pain and again 24 hours later. Bowels moved on day before admission following dose of castor oil and salts.

Physical examination on admission. Respiratory movements of abdominal muscles restricted. Acute tenderness is present in right lower quadrant from McBurney's point downward to Poupart's ligament. Right rectus muscle spasm is present but no definite rigidity. Rebound tenderness is present on both sides of abdomen. Temperature 100.8°. Pulse 116. Leucocytes 17,400. Polymorphonuclears 84 per cent.

Findings at operation, April 23, 1918. Moderate amount of cloudy, brownish, colon-smelling exudate escaped when peritoneum was incised. Appendix was latero-cæcal in position and was gangrenous in its middle third, a large perforation being present and a fæcal concretion was found lying free at this point. Mesentery was infiltrated and bound down to posterior parietal wall. Cæcal wall was moderately œdematous. Exudate was present in the pelvis.

Procedure. A 4 inch right rectus incision through the muscle was made. Cæcum was drawn into wound, meso-appendix ligated and divided; appendix amputated, stump inverted, purse-string of Pagenstecker, reinforced by suture of plain gut used to close in the site. Pelvic exudate removed by suction and fenestrated soft rubber drainage tubes containing plain gauze packing were placed to depth of pelvis and to cæcal region. Peritoneum closed tightly about tubes by continuous plain gut. Gauze packing introduced into space between tubes to aid in sealing off peritoneal region from the wound. Rectus muscle was approximated, by interrupted plain gut, fairly snugly about the tubes. Anterior rectus sheath approximated by interrupted heavy plain catgut placed in a manner to slightly overlap the edges. Angles of skin incision with panniculus approximated by interrupted silkworm gut. Two Carrel 5 centimeter tubes placed in superficial wound resting upon the surface of anterior sheath. Wound dressings arrangement as in preceding case.

Pathological report. Gross. Specimen is an appendix, 9 centimeters long, which is clubbed at the tip and is 1 centimeter in diameter. The surface is here and there necrotic, dusky red, and presents numerous fibrous adhesions and also some fibrinous exudate. At the proximal end of the distal bulge there is a perforation with more or less necrotic walls. Cut section of the bulged tip shows a very thickened wall with an obliterated lumen. Proximally the wall is thickened, the lumen small, and the diameter only ½ centimeter.

Microscopic. Cross section of the narrow portion of the appendix shows very marked congestion of the subserosal vessels together with hæmorrhage and round-cell infiltration. There is slight necrosis of the surface. All the coats show some round-cell infiltration and chronic inflammation. The lymphoid element is almost gone. The mucosa is atrophic but intact. The lumen is empty. Section through the bulbous tip shows enormous thickening of all the coats together with marked polynuclear infiltration, hæmorrhage, necrosis and throughout is the evidence of a chronic inflammatory process with fibrosis. The lumen is lined by necrotic tissue.

Bacteriological report. Culture of exudate: bacillus coli communis, non-hæmolytic streptococcus.

Postoperative wound treatment. Second day. Drainage from peritoneal cavity has been very slight. The gauze packing removed at end of 24 hours had a sulphurous odor. It was replaced by packing saturated with 5 per cent dichloramine-T.

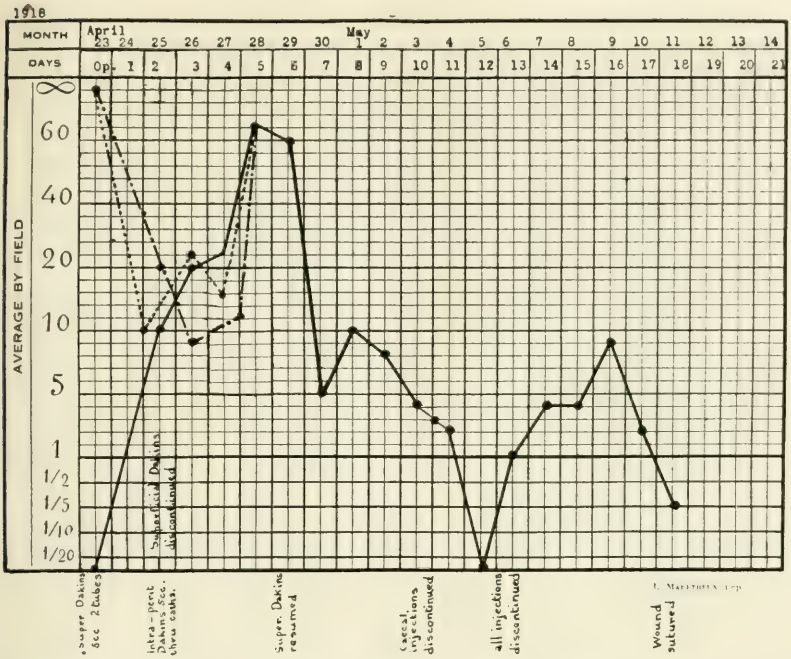

Chart 5. J. L. Ward 10, History No. 37,983. Acute appendicitis with acute local peritonitis; perforated appendix; free, foul exudate. ——— Superficial. – – – – Cæcal. –·–·–·– Pelvic.

The packing removed today had a "sour" odor. Superficial wound appears clean. The packing between the drainage tubes removed and replaced. No. 14 French catheters placed to depth of drainage tubes and sodium hypochlorite solution ordered in 2 cubic centimeter amounts every two hours. Wound dressings applied as at operation.

Fourth day. Patient in excellent general condition. No. 18 French soft rubber catheters introduced to depth of drainage tracts and the rubber tube drains removed. Carrel tubes in superficial wound removed. Trial injections returned freely. Superficial wound presents patches of greyish slough along one area which has been in contact with the Carrel tubes. 5 cubic centimeters sodium hypochlorite solution ordered every two hours in cæcal and pelvic tracts. Single layer dressing applied.

Sixth day. Superficial Carrel tube replaced yesterday as wound had become lined by dark grey slough. There is a moderate amount of light brownish discharge having slightly disagreeable odor.

Eighth day. Wound appears cleaner; pink granulations presenting between narrow strips of whitish slough. Discharge from wound is moderate and has a slight colon odor.

Tenth day. Small amount of light colored odorless discharge. Wound lined by bright red granulations except small area in depth of wound which presents a whitish slough. Cæcal tract has shortened to such an extent that instillation catheter was removed; partially absorbed catgut sutures free in wound. Bacterial count less than 10 per field.

Thirteenth day. Slough has completely disappeared; wound is lined by coral-red granulations; discharge shows no organisms. Hypochlorite solution discontinued; wound strapped and zinc sulphate wet dressing applied.

Eighteenth day. There has been slight mucoid discharge from wound. Bacterial smears showed a reappearance of organisms following discontinuence of the hypochlorite injections describing a curve to 9 organisms per field and today the count is 1 organism per 5 fields. Wound closed by silkworm sutures.

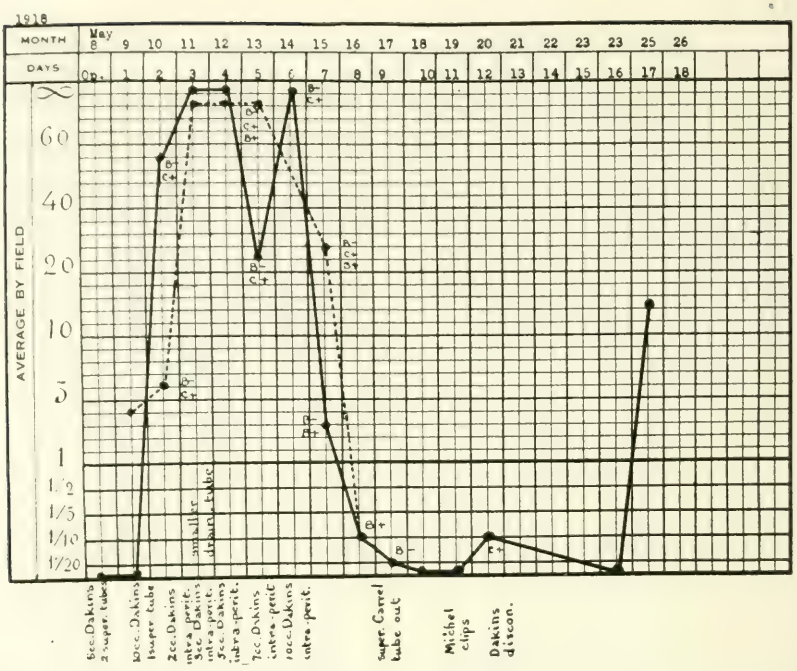

Chart 6. M. B., Ward 10, History No. 38,106. Acute appendicitis with peritoneal abscess, pelvic. ——— Superficial. – – – – Pelvic.

Twenty-second day. Sutures removed; epithelization has taken place along upper portion of wound; there remains a superficial granulating area, 5 millimeters wide and 2 centimeters long at lower angles. Probe can be entered in this area to depth of 2.5 centimeters and small amount of whitish exudate can be expressed. Small amount of exudate can also be expressed from stitch holes.

Twenty-sixth day. Patient discharged with superficial granulating area 5 millimeters by 1 centimeter, admitting probe 2.5 centimeters. Secretion negligible and serous in character. Abdominal wall firm and no tenderness present.

Follow-up notes. 3 months: small sinus persists due to presence of chromic suture. Sinus closed immediately after removal. 7 months: on coughing, there is a slight bulge in center of wound.

Case 6. M. B. History No. 38106. American, male, age 19. Admitted May 7, 1918. Discharged June 1, 1918.

History of present attack. Onset of pain in hypogastrium 11 days before admission; vomiting and fever was present at onset and patient confined to bed for 1 week. During past 4 days constant dull pain in right lower quadrant accompanied by nausea.

Physical examination on admission. Abdomen is held rigidly, about equal on either side; no mass and no tenderness on deep pressure; no rebound tenderness. Rectal examination, negative. Temperature 99.4°. Pulse 120. Leucocytes 22,500. Polymorphonuclears 86 per cent.

Findings at operation. (Operator, Dr. Lambert.) Appendix lay in pelvic position, attached by short meso-appendix to posterior parietal wall. It was acutely inflamed throughout. Surface covered by fibrinopurulent exudate. There was a small amount of thick, purulent, but odorless, exudate surrounding appendix.

Procedure. Oblique intermuscular incision. Appendix removed, stump inverted by purse-string of Pagenstecker, reinforced by plain gut suture. One large (1 centimeter lumen) fenestrated rubber drainage tube containing strip of gauze packing placed to depth of pelvis. Peritoneum closed tightly about drain and muscle planes by interrupted plain gut sutures; angles of skin approximated by interrupted silkworm gut. Two Carrel tubes open at ends placed in superficial

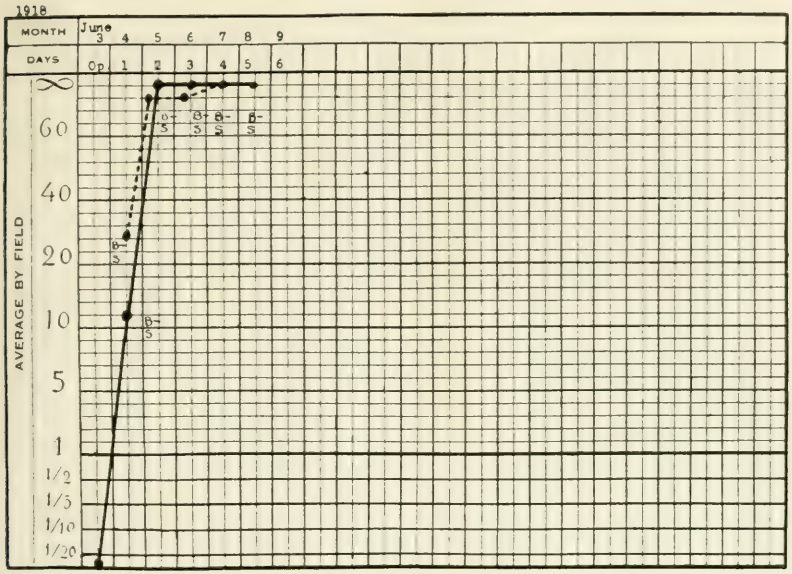

Chart 7. C. R., Ward 8, History No. 38.329. Acute appendicitis with peritoneal abscess, pelvic. ——— Superficial. – – – – Pelvic.

wound lying on external surface of aponeurosis. Mid-portion of wound left unsutured and was packed loosely with bandage gauze.

Wound dressing. Same as preceding case, except for slight modification by placing a piece of rubber dam over projecting end of drainage tube to insure more perfect isolation of the superficial wound.

Pathological Report No. 21213. Gross. Specimen consists of an appendix, 5 centimeters long and 1½ centimeters across at the clubbed tip. The proximal portion is small and twisted upon itself and the distal part shows firm adhesions, congestion and thickening of the wall.

Microscopic examination. The wall of the appendix is tremendously thickened especially the subserosa which near the meso-appendix shows a mass of myxomatous tissue and elsewhere a cellular young connective tissue through which are scattered many congested blood vessels and here and there are areas of hæmorrhage. There is in addition a cellular exudate, of round and eosinophile cells. The muscular coats are likewise infiltrated. The submucosa is rather thin but shows some evidence of a chronic inflammation. The lymphoid tissue is small in amount and the mucosa is largely missing owing apparently to technique rather than necrosis.

Bacteriological report. Culture of exudate: no growth. Smear of exudate: gram positive coccus (streptococcus?).

Postoperative care of wound. Five cubic centimeters sodium hypochlorite solution injected through superficial tubes every two hours, beginning at end of operation.

First day. Considerable thin hæmorrhagic serum on dressings in contact with drainage tube. Gauze removed from tube and replaced by packing saturated with 5 per cent dichloramine-T solution. Dressings replaced as at operation.

Second day. Gauze packing removed from drainage tube and No. 12 French catheter introduced with narrow gauze packing and sodium hypochlorite solution ordered in 2 cubic centimeter amounts every 2 hours.

Third day. Small fenestrated drainage tube introduced within the larger one, the latter then being withdrawn. Catheter replaced in the smaller tube and amount of solution increased to 3 cubic centimeters every 2 hours. There is a slight colon odor to discharge; superficial wound remains clean. Single layer dressing.

Fifth day. Discharge from wound light brown with definite colon odor. No. 18 French catheter introduced to depth of drainage tract and drainage tube re-

moved. Five cubic centimeters sodium hypochlorite has been injected every two hours since yesterday and 10 cubic centimeters superficially. The wound shows slight amount of slough in isolated areas.

Seventh day. Odor of exudate has disappeared; wound presents a very little superficial whitish slough; it is lined for the most part with bright red granulations. Sutures removed from angles. Ten cubic centimeters of solution has been injected intraperitoneally for past 24 hours. No. 18 French catheter replaced by No. 10 French. Superficial Carrel tube left in place.

Ninth day. Discharge has practically ceased; slimy exudate alone present. Wound strapped at angles. Bacterial count 1 in 10 and 1 in 20 fields. Culture taken shows bacillus pyocyaneus.

Eleventh day. Edges of wound approximated by Michel clips, allowing space for catheter which now rests at depth of 4 centimeters. Solution 5 cubic centimeters every 2 hours.

Twelfth day. Solution discontinued. Zinc sulphate wet dressings applied.

Sixteenth day. Michel clips removed; edges have separated in middle third of approximated line. Wound strapped. There has been a slight amount of whitish, odorless exudate present on dressings daily and bacterial count has risen to 15 organisms per field. Wound is lined throughout by bright red granulations and drainage tract has closed in, probe entering only about 2.5 centimeters.

Twenty-third day. Patient leaves hospital with superficial granulating area, 1.5 centimeters long and 5 millimeters wide.

Follow-up notes. 2 months: general condition excellent; there is a tiny granulating point at lower angle of incision; wall firm. 6 months: abdominal wall at site of scar is firm.

Case 7. C. R. History No. 38329. American, female, age 11. Admitted June 2, 1918. Discharged July 12, 1918.

History of present attack. Onset with vomiting 4 days before admission. Epigastric pain followed vomiting and localized after 24 hours in the right lower quadrant. Catharsis given first day of attack. Vomiting has been prominent symptom. Pain and tenderness extreme during 24 hours previous to admission.

Physical examination on admission. Poorly nourished child lying with both thighs flexed, complaining of extreme abdominal distress when disturbed. She appears acutely ill, tongue dry and coated. Temperature 102.4°, pulse 140, respiration 40. Leucocytes 26,000, polymorphonuclears, 92 per cent. Heart: blowing systolic at apex. Urine: Heavy trace of albumin; hyaline and granular casts. Abdominal examination: Respiratory movements restricted. There is acute tenderness over entire right lower quadrant and definite rigidity in same area. Rectal examination: Acute tenderness and mass palpable high up on right side.

Findings at operation. Moderate amount of cloudy exudate free in cavity. Appendix gangrenous but not perforated; lay over brim of pelvis, its tip surrounded by pus having faint colon odor. Attachment of appendix to cæcum was in close proximity to ileocæcal junction. Mesentery was narrow and œdematous.

Procedure. Oblique incision in right lower quandrant; intermuscular approach. Appendix removed; stump inverted and site reinforced with plain gut. A single large, thin walled, fenestrated drainage tube (1 centimeter lumen) packed with plain gauze introduced to depth of pelvis. Peritoneum closed tightly about tube by purse string. Muscle planes to aponeurosis approximated by interrupted plain gut. Figure-of-eight silkworm sutures placed in skin including aponeurosis. Two small Carrel tubes placed in superficial wound extending but a short distance (1.5 centimeters) along sutured aponeurosis. Separation type of dressing applied.

Pathological report. Gross: Specimen consists of an appendix, 4½ centimeters long, 0.7 centimeters at the base, and 0.9 centimeters near the tip. The distal third is light grey in color. The peritoneal covering is relatively smooth with a few small shreds of fibrin in places. The lumen is present and contains a fæcalith at the junction of the middle and distal thirds.

Microscopic examination. The structure of the appendix wall has almost completely disappeared and in some areas the cells have completely lost their staining quality. There are large areas consisting entirely of large masses of polynuclear cells and other areas showing hæmorrhage.

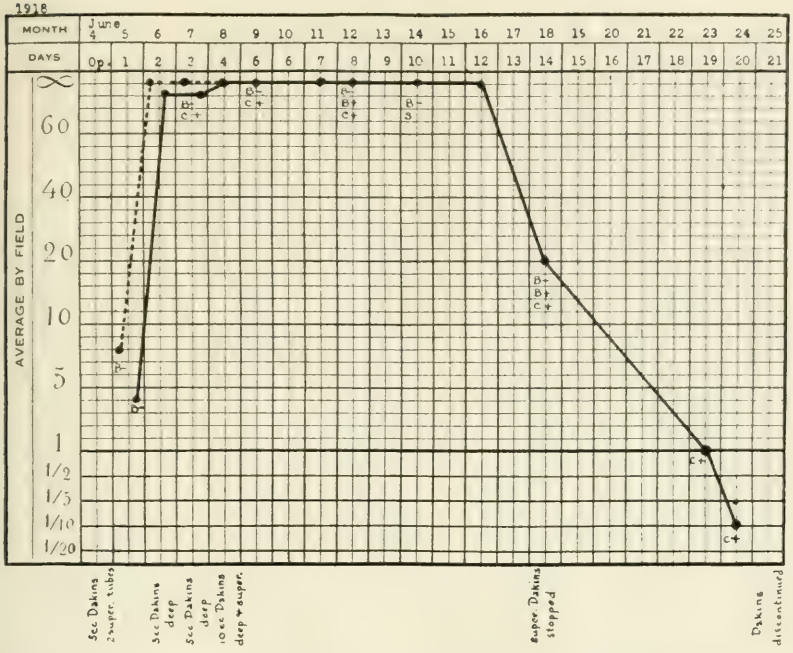

Chart 8. F. W., Ward 10, History No. 38,354. Acute appendicitis with peritoneal abscess, retrocæcal. ——— Superficial. – – – – Cæcal.

Bacteriological report. Streptococcus viridans, bacillus coli communis.

Postoperative care of wound. 12 hours postoperative: dressings moderately stained with exudate; packing in drainage tube replaced by 5 per cent dichloramine-T packing.

First day. 36 hours postoperative: discharge from drainage tube has foul colon odor. 5 per cent dichloramine-T packing replaced. Patient's abdomen moderately distended, tender.

Second day. Packing removed from tube and No. 12 French catheter introduced. Three cubic centimeters Dakin's ordered every 2 hours. Distention less; patient complaining of continued abdominal pain, of cramp-like character.

Third day. Skin sutures showing considerable irritation; wound lined by grey slough. Discharge moderate in amount but foul, colon-smelling. Smaller fenestrated drainage tube inserted in place of one placed at operation, and 5 cubic centimeters Dakin s ordered through catheter placed within its lumen. Superficial Carrel tubes have tendency to become displaced; one removed and 10 cubic centimeters Dakin's ordered through remaining tube. Child fretful, abdomen somewhat distended, still complains of cramps.

Fourth day. Brownish, colon-smelling exudate, No. 18 French catheter introduced and drainage tubes removed. Last injection returned freely. Colic continues and visible peristalsis is present during attack.

Fifth day. Vomiting of upper intestinal contents. Lavage given and ordered repeated. Wound sutures cutting out; slough removed from aponeurotic plane Method of wound treatment has been a complete failure.

Sixth day. Patient showed temporary improvement from lavage; tongue becoming moist, pain relieved for about 12 hours. During the day abdomen again became distended, peristalsis visible and synchronous with attacks of colic. She again began to vomit upper intestinal contents. She has had no satisfactory bowel movement since operation although gas has passed freely at times. Sutures all removed from wound together with considerable slough, leaving clean granulating surface. Discharge has a colon odor. Patient seen by Dr. Auchincloss, and intervention for relief of mechanical ileus was decided upon.

June 9, 1918. Exploratory cœliotomy for acute ileus—Dr. Auchincloss. Exploration through wound. A kink of ileum was found at brim of pelvis, deep in; it made up a portion of the wall of the drainage tract. Intestine was distended above and collapsed below this loop. Gas passed readily after complete freeing of loop. The sinus tract that had been treated with Dakin's fluid was pretty clean; only a little residual pus in tract; granulations lining it were red, exuberant, well nourished. Cigarette drain to brim of pelvis. Wound sutured with interrupted silkworm-gut through all layers.

Course following second operation. Within a few days patient was having free through-and-through movements, taking soft diet without distress. Wound suppurated freely, grey colon pus being present on dressings in profuse amount for 7 days. The wound edges separated considerably after 3 to 4 days and was packed daily with 5 per cent dichloramine-T. Cigarette drain was removed and replaced by small rubber tube on the fifth day. Sutures removed on eighth day and edges strapped together. Dichloramine-T packing was discontinued on the tenth day; granulations appearing exuberant and rather dusky and unhealthy. Balsam of Peru and castor oil packing introduced. On twelfth day drain removed and sinus packed lightly with balsam of Peru gauze. On July 9, one month after second operation, narrow ridge of granulations about 2 centimeters in length. Patient up and about.

Follow-up notes. General condition good. Scar is wide and irregular; there is a ventral hernia present, corresponding with the upper two-thirds of the scar.

Case 8. F. W. History No. 38354. Austrian, male, age 36. Admitted June 4, 1918. Discharged June 26, 1918.

History of present attack. Onset of pain in right lower abdomen 9 days before admission, accompanied by vomiting and continued fever. Swelling has been noticeable past 3 days. Tenderness has persisted; patient has had chilly feelings.

Physical examination on admission. Tender, fixed, elastic mass about 5 to 6 centimeters in diameter, in right lower quandrant reaching to level of 1 to 2 centimeters above umbilical line. Temperature 102.2°. Pulse 104. Leucocytes 20,000. Polymorphonuclears, 78 per cent.

Findings at operation. Small amount of free, cloudy peritoneal fluid. Mass was found to be retrocæcal. On raising cæcum and ascending colon a large abscess cavity was found, containing fæcal-smelling pus, fæcaliths and what was taken to be slough of appendix. The entire cæcal wall was greatly thickened by œdema and base of appendix could not be located.

Procedure. Eight centimeters oblique intermuscular incision with Weir extension. Cæcum and ascending colon mobilized by incision of parietal peritoneum, abscess cavity opened and evacuated of contents. After fruitless search for appendix, a large fenestrated rubber tube lightly packed with gauze was introduced and peritoneum closed snugly about it. Muscle planes and aponeurosis approximated by interrupted plain gut, and skin by silkworm-gut. Two Carrel tubes placed subcutaneously along line of sutured aponeurosis. Separation type of dressing applied.

Pathological report No. 21356. Gross. Specimen consists of four pieces of tissue; the largest is 2.5 by 4 by .2 centimeters. It is soft in consistency and contains what appears to be fatty tissue and shows some hæmorrhage. The second piece consists mostly of fatty tissue. The two other pieces are blackish blue and very soft and on section appear to be blood clot.

Microscopic examination. The mucous membrane is destroyed and the whole wall is hæmorrhagic and œdematous. Another section shows connective tissue with round-cell infiltration and in other parts œdema. Other places present hæmorrhagic infiltration.

Bacteriological report. Culture of pus: bacillus coli communis.

Postoperative care of wound. Five cubic centimeters sodium hypochlorite solution injected in superficial tubes from time of operation.

First day. Thin hæmorrhagic exudate on both layers of dressing. Gauze packing in tube replaced by 5 per cent dichloramine-T packing.

Second day. 48 hours postoperative. Gauze packing removed from tube and No. 10 French soft rubber catheter with narrow strip of packing introduced. Three cubic centimeters sodium hypochlorite ordered every 2 hours intra-abdominally.

Third day. 72 hours postoperative: moderate amount of brownish, foul, colon-smelling discharge on dressing. Instillation catheter and packing removed

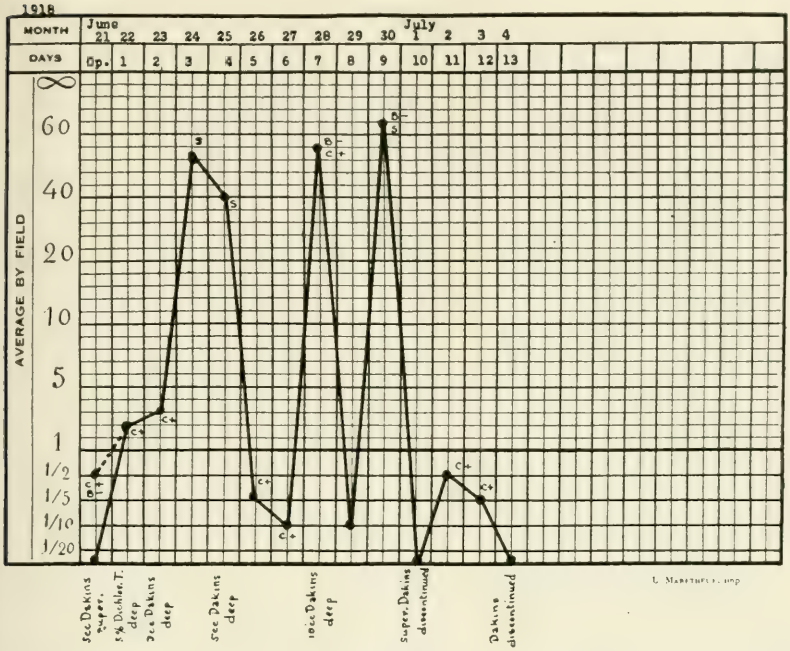

Chart 9. B. H., Ward 8, History 38,485. Acute appendicitis with acute local peritonitis. Gangrene and perforation of appendix. ——— Superficial. – – – – Pelvic.

from drainage tube; a smaller fenestrated drainage tube introduced and the one placed at operation removed. Catheter replaced in the smaller tube and 5 cubic centimeters solution ordered every 2 hours. Trial injection of saline returned freely both within and outside of tube.

Fourth day. 96 hours postoperative: general condition excellent. Discharge dark brown, colon odor. Moderate redness of wound but sutures not cutting. No. 18 French catheter introduced to depth of tract and drainage tube discontinued. Ten cubic centimeters solution ordered in each of the tubes (two superficial; one deep).

Seventh day. Injections have been continued. Wound has been discharging slightly colon-smelling pus. There was a superficial slough lining the wound from the fourth to sixth day which has disappeared without separation of any portions of macroscopic size. Sutures are showing practically no irritation.

Tenth day. During past 3 days patient has had temperature, rising on the eighth day to 103°. There was no increase in wound tenderness, but slight change in character of discharge, becoming more brownish in color. Leucocytosis 20,400. Polymorphonuclears 82 per cent on the eighth day. Sutures removed today.

Fourteenth day. Temperature has declined; wound region soft and not tender. Discharge odorless; few shreds have returned when wound has been irrigated during dressings. Wound is lined throughout by bright red granulations. Superficial tubes removed and No. 14 French catheter introduced to depth of abdominal tract.

Twenty-first day. Sinus now about 6 centimeters deep and too narrow for instillations. Discharge negligible. Wound strapped; dry dressing. Patient allowed up.

Twenty-fifth day. Scar is a fine, pink line; wound at lower angle admits probe 1 centimeter and edges are slightly gaping for 1 centimeter. Abdominal wall is firm; no deep tenderness. Patient discharged.

Follow-up notes. 2 months: general condition excellent. Abdominal wall is firm throughout.

Case 9. B. H. History No. 38485. American, female, age 17. Admitted June 20, 1918. Discharged July 13, 1918.

History of present trouble. Gradual onset of pain in lower abdomen 3 days before admission, accompanied by nausea. Pain remained about the same until evening of third day when it became aggravated and patient vomited and became prostrated.

Physical examination on admission. Appears acutely ill, dry parched lips, coated tongue, anxious pinched face. Temperature 103.2°. Pulse 118. Respiration 32. Leucocytes 24,000. Polymorphonuclears 95 per cent. Abdomen: definite rigidity in both lower quadrants, more on right. Tenderness over wide area in right lower quadrant centering about McBurney's point. On rectal examination there is a boggy tender mass high up on the right side.

Findings at operation. Small amount of cloudy odorless peritoneal exudate. Peritoneum of small intestinal coils slightly injected. Appendix lay over pelvic brim, acutely inflamed with perforation near the tip, from which greenish pus with colon odor was exuding.

Procedure. Six centimeters oblique incision, intermuscular approach to peritoneum. Appendix removed, stump inverted by purse string of Pagenstecker, re-inforced by plain gut sutures. In dividing meso-appendix a small portion of serous coat of appendix was left included in ligated stump. Double drainage tube, one fenestrated and containing gauze packing, the other empty and non-fenestrated introduced to depth of pelvis. The tapered ends of these tubes were held together by loop of fine plain gut. Peritoneum and muscle planes closed about tubes as in preceding case. Carrel tubes placed subcutaneously along sutured aponeurosis.

Pathological report No. 21438. Gross. Specimen consists of an appendix, 4 centimeters long and 1 centimeter in diameter. It is constricted 1½ centimeters from the tip. The peritoneal surface is roughened and fibrinous. On section the wall is greatly thickened, the lumen not admitting a small probe throughout its entire length. There is no fæcal material present in the proximal two-thirds but in the clubbed tip there is a fæcalith of a hard and pasty consistency, 1 centimeter by 3 millimeters.

Microscopic examination. Section shows an appendix with absent mucosa; the submucosa is œdematous and fragmented with its strands extending into the lumen. The muscularis is slightly œdematous, hæmorrhagic and infiltrated throughout with round cells. There is a thick coating of fibrin containing a considerable amount of extravasated blood and being also infiltrated with round cells. Another section shows the wall of the appendix markedly hæmorrhagic and infiltrated with leucocytes. The adjoining peritoneum is also filled with extravasated blood and well infiltrated with round cells.

Bacteriological report. Peritoneal exudate: streptococcus, gram negative bacillus.

Wound treatment. 12 hours postoperative: dressings changed; gauze packing removed from drainage tube and replaced by packing saturated with 5 per cent dichloramine-T.

First day. 36 hours postoperative: moderate amount of light yellowish exudate from deep wound having sulphurous odor. 5 per cent dichloramine-T packing replaced and 2 cubic centimeters dropped in the free tube.

Second day. 60 hours postoperative: Non-fenestrated tube removed; fenestrated tube loosened, packing removed and No. 12 French catheter introduced within its lumen to depth of tract. Trial injection of saline returned freely about tube. Three cubic centimeters Dakin's fluid injected without pain and ordered every 2 hours. Patient's general condition excellent.

Fourth day. No. 18 French catheter substituted for the smaller one and fenestrated drainage tube removed. Five cubic centimeters Dakin's ordered in deep tract. Wound clean, stitches not cutting, exudate has yellowish, slimy appearance and slight chlorine odor.

Seventh day. Dakin's has been continued in 5 cubic centimeter amounts in superficial and deep tubes. Today for the first time there is slight colon odor to discharge and bacterial count which has been running below one per field for past 2 days has risen to 58 per field. Dakin's fluid increased to 10 cubic centimeters every 2 hours in deep tract. Sutures removed from angles.

Tenth day. Wound has been lined by bright red granulations for past 4 days; there has been no odor to discharge since Dakin's fluid was increased. Bacterial count has fluctuated, however, yesterday being 64 per field; today no organisms

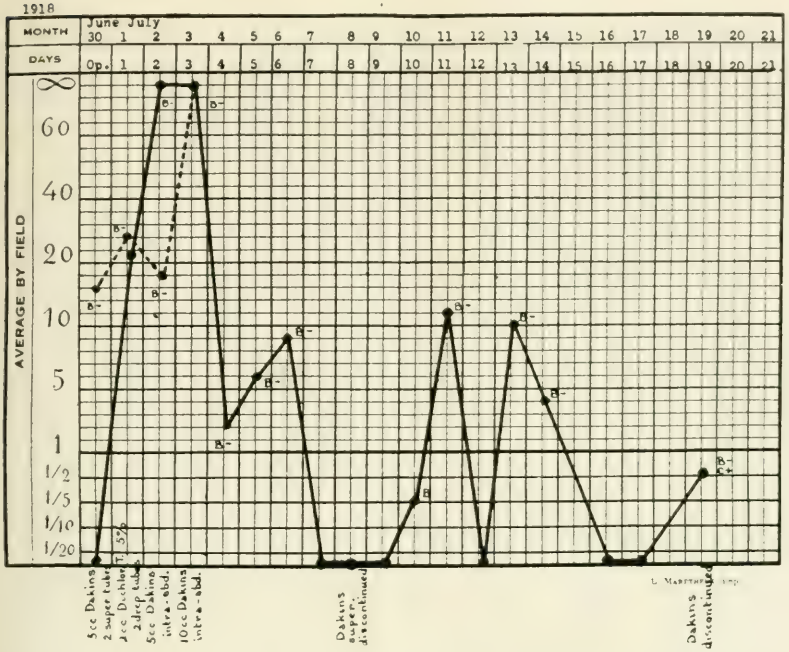

Chart 10. J. MacG., Ward 10, History No. 38,561. Acute appendicitis with peritoneal abscess, retrocæcal. ——— Superficial. – – – – Cæcal.

found. Superficial Carrel tubes removed today and deep catheter, now No. 14 French shortened 2 centimeters. All sutures out.

Thirteenth day. Bacterial count less than 1 per field during past 3 days. Discharge from wound has practically ceased, a small spot of slimy exudate only present. Today's 9 a. m. injection of 10 cubic centimeters Dakin's was given by syringe with more than usual force. The patient experienced a sharp pain in hypogastrium and for 2 hours was very uncomfortable. At 11 a. m. the wound was dressed. Patient did not report experience of previous injection. Ten cubic centimeters Dakin's was injected and failed to return. Pain was immediate, sharp, localized in hypogastrium, and caused her to cry out. She perspired profusely and pain continued during the ensuing 12 hours. Temperature and pulse had been normal and increased to 100.8°, pulse 100 during the following day, then subsiding again to normal. Tract was undoubtedly disrupted by forcible injection and fluid went into pelvis. Granulations had closed in rather tightly about the catheter which passed to a depth of about 7 centimeters. Inasmuch as tract was clean no serious outcome resulted but the experience indicates clearly *the necessity of maintaining ample space about the instillation tubes for a free return; likewise the advisability of slow, gentle introduction of fluid.* Injections were discontinued and moist zinc sulphate dressing applied.

Seventeenth day. Wound clean today. There is a healing sinus about 1.5 centimeters in length, 0.5 centimeters in width, and 1 centimeter in depth. Abdominal wall appears firm. Wound strapped tightly and patient allowed up.

Follow-up notes. 3 months: Wound was healed one week after leaving hospital; scar is now a fine, pink line; wall firm. 5 months: general and local condition excellent.

Case 10. J. Mac G. History No. 38561. Scotch, male, age 51. Admitted June 29, 1918. Discharged July 23, 1918.

History of present trouble. Attack of abdominal pain 6 weeks before admission; pain continued for 3 days in right lower abdomen; tenderness persisted in same region for one week. Thirty hours before admission, general abdominal distress, nausea but no vomiting, pain with acute tenderness rapidly localizing in right lower abdomen.

Physical examination on admission. Abdomen prominent but not apparently distended. In right lower quadrant there is acute tenderness, reflex muscle spasm and a feeling of mass, the outlines of which are indefinite. Rebound tenderness is present in all quadrants. High tenderness present by rectum. Temperature 99.6°, pulse 96. Leucocytes 19,000. Polymorphonuclears 96 per cent.

Findings at operation. Pronounced œdema of properitoneal fat; no free peritoneal exudate. Omentum œdematous; attached to under surface of cæcum. Cæcum with adjacent coils of intestine involved in partially organized adhesions indicating process of some duration. Appendix was retrocæcal surrounded by 5 to 6 cubic centimeters thick, yellowish pus. Appendix immediately surrounded by thick, fibrinopurulent membrane. Appendix pointed upward and outward.

Procedure. Six centimeters oblique incision, intermuscular, with Weir extension. Omentum separated from its cæcal attachments; cæcum mobilized by breaking through adhesions from outer side. Appendix freed from cæcal attachment; mesentery clamped and divided. Base of appendix crushed and doubly ligated with chromic gut, amputated and stump cauterized. Double drainage tube, tapering ends united by untied loop of fine catgut; one tube fenestrated and lightly packed with gauze, the other non-fenestrated and not packed, placed to retrocæcal region. Abdominal wall closed in layers by interrupted catgut. Silkworm-gut sutures placed at either angle of skin incision. Two Carrel tubes were placed in subcutaneous plane along sutured aponeurosis. Two strips of gauze packing placed in angles between drainage tubes. Separation type of dressings. Injections of 5 cubic centimeters Dakin's begun immediately in superficial Carrel tubes.

Pathological report. Gross. Specimen consists of an appendix, 4 centimeters long, which is moderately clubbed at the tip. With the exception of the distal enlargement the diameter is fairly uniform throughout. The peritoneal surface is covered by a layer of fibrin which forms a close attachment between the appendix and surrounding fat. The mesentery is attached throughout and plentifully supplied with fat. On section the wall is markedly thickened; the lumen not admitting the point of a small probe. No cæcal material is present. There is also a separate piece of thin, firm tissue, 4 by 2 centimeters.

Microscopic. The mucosa of the appendix is intact with the normal relation between glandular and lymphoid tissue. There is slight œdema of the submucosa as well as a considerable quantity of fat. The inner layer of the muscularis is greatly thickened, measuring three or four times that of the average and is intact throughout as in the outer layer. The surrounding peritoneum shows evidence of a moderate amount of hæmorrhage and round-cell infiltration. There is a moderate round-cell infiltration of all coats, the mononuclear type predominating. The second specimen is a bit of peritoneum, hæmorrhagic in spots and infiltrated with round cells. In one area there is considerable fibrin formation which also shows evidence of inflammation and hæmorrhage.

Bacteriological report. Peritoneal exudate: smear, streptococcus. Gram negative bacillus. Culture: bacilli coli communis.

Postoperative wound treatment. Ten hours postoperative: Moderate amount of exudate in both dressing layers; more in those in contact with wound. Dressings changed. Two cubic centimeters 5 per cent dichloramine-T dropped in each drainage tube.

First day. 34 hours postoperative: moderate amount of superficial and deep discharge, the deep having slight colon odor. Packing removed from fenestrated tube and replaced by fresh gauze, saturated with 5 per cent dichloramine-T. Two cubic centimeters also dropped in the other tube.

Second day. Slight amount of discharge; no odor. Non-fenestrated tube removed and packing removed from the other tube. No. 12 French catheter placed to depth of remaining tube and test solution returned freely both within and around tube. Five cubic centimeters Dakin's solution introduced without pain. Single layer dressing.

Third day. Slight amount of light grey, odorless exudate. No. 19 French catheter substituted for No. 12 catheter and drainage tube removed. Intra-abdominal injections of Dakin's increased from 5 to 10 cubic centimeters. Superficial injections of 5 cubic centimeters in each tube. Injections cause no discomfort.

Fifth day. General condition excellent; discharge slight, greyish, slimy; chemical odor. Moderate wound redness but no separation of approximated edges.

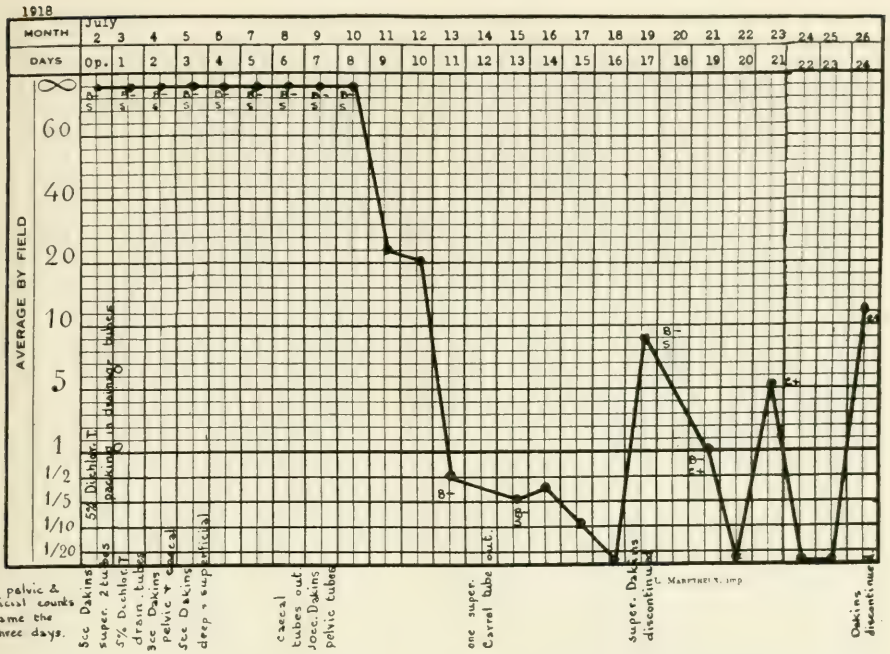

Chart 11. H. A., Ward 10, History No. 38,578. Acute appendicitis with peritoneal abscess, subcæcal.

Eighth day. Sutures removed on the sixth day; edges holding; discharge remains slight in amount; superficial Carrel tubes discontinued. Wound lined by pink granulations. No. 14 French catheter substituted.

Twelfth day. Tract has narrowed down to a small but rather deep 6 centimeter sinus. Small Carrel tube substituted for the catheter.

Nineteenth day. Dakin's solution has been continued long after drainage might safely have been discontinued, in order to determine period of disappearance of organisms. The bacterial count has fluctuated between no organisms on the seventh day and 12 organisms on the eleventh day. No organisms have been reported the past 2 days and tract is now but 2 centimeters in depth and too narrow for further treatment.

Twenty-third day. Patient discharged with clean crust covering drainage site and firm abdominal wall.

Follow-up notes. 3 months: general condition excellent; scar is a fine white line; wall firm.

Case 11. H. A. History No. 38578. American, male. Age 21. Admitted July 2, 1918. Discharged August 1, 1918.

History of present illness. Onset 4 days before admission with general abdominal cramps localizing in right lower abdomen after 24 hours. Vomiting on second day of attack and several times since. Anorexia and fever.

Physical examination on admission. Distinct, well outlined mass in right lower abdomen extending from just below umbilical line to Poupart's and from a vertical line 2 centimeters to the right of mid-line well out to right flank. Mass is exceedingly tender and muscles overlying are rigid. Temperature 102.4°, pulse 84. Leucocytes 19,500. Polymorphonuclears 92 per cent.

Findings at operation. On opening the peritoneal cavity there was a gush of a quantity of greyish pus having a fæcal odor. A large abscess cavity was found occupying the right lower abdomen, the walls of which were composed of adherent coils of intestine, omentum, and parietes. A thick, dirty membrane lined the cavity. The appendix lay in the depth of the cavity pointing upward along the outer surface of the cæcum. Its base was made up a portion of the lower wall of

the cavity and upon its removal the uninvolved pelvic area was opened up. The appendix was gangrenous.

Procedure. Six centimeters oblique, intermuscular incision. Abscess cavity evacuated and appendix removed in usual manner stump being inverted and site reinforced by plain catgut sutures and by bringing meso-appendix over the area. Double drainage tube similar to that used in preceding case introduced to pelvis and a single fenestrated packed tube to cæcal region. The packing in the tubes was saturated with 5 per cent dichloramine-T solution. Abdominal wall closed in layers by interrupted plain gut and interrupted silkworm-gut in skin to subcutaneous plane. Wound washed out with Dakin's solution during suture. Two Carrel tubes in subcutaneous area along surface of aponeurosis. Strips of vaseline gauze introduced between angles of drainage tubes to lessen contamination of superficial wound by the peritoneal exudate. Separation type of dressings. Five cubic centimeters Dakin's injected superficially on table.

Pathological report No. 21490. Gross. Specimen consists of an enormous appendix, 1½ centimeters at the widest point and 6 centimeters long. The meso-appendix is greatly thickened. The surface is brownish green and very turgid. On the surface also there is a fibrinopurulent exudate and at scattered areas some gangrene. Section shows the wall necrotic and greenish grey; the lumen contains soft fæcal material and the meso-appendix is definitely thickened.

Microscopic. The appendix is almost entirely gangrenous in this section. The subserosa is very thick and, like all the coats, shows broken-down masses of polynuclear leucocytes. The submucosa is thickened by a very cellular exudate and is also necrotic. The lymphoid and mucous coats are wanting.

Bacteriological report. Non-hæmolytic streptococcus, bacillus coli communis.

First day. Drainage from peritoneal cavity thin, reddish, foul colon odor; superficial drainage slight. Packing from fenestrated tubes removed and replaced by fresh gauze saturated with 5 per cent dichloramine. Vaseline strip removed; separation dressings replaced.

Second day. Moderate amount of colon discharge on superficial and deep dressings; tube packing saturated with dark brown colon discharge. Wound shows moderate redness and œdema about stitches. Non-fenestrated tube to pelvis removed and fenestrated tube loosened and slightly shortened, about 1 centimeter. No. 10 French catheter introduced to depth of pelvic and cæcal tubes and 3 cubic centimeters Dakin's ordered in each tube. Trial injection of saline returned freely both within and about cæcal tubes but returned only within, in case of pelvic tube.

Third day. Patient's general condition excellent. No. 19 French catheter substituted for No. 10 French catheter in cæcal drainage tube, the latter being removed. Smaller fenestrated drainage tube with No. 10 catheter substituted for the larger pelvic tube. Five cubic centimeters Dakin's ordered in all tubes superficial and deep.

Sixth day. Arrangement of tubes and injections have remained the same. Discharge now small in amount, light brownish in color and has faint colon odor. No. 18 French catheter introduced in pelvic drainage tract, the tube being discontinued. Catheter in cæcal drainage tract discontinued as tract had shortened and freely communicates with pelvic tract.

Seventh day. Wound irrigated with salt solution, a rather large, soft, ragged slough coming from the deep portion of tract, probably separated abscess wall. Silkworm sutures removed, wound strapped. Ten cubic centimeters Dakin's ordered in deep tract.

Twelfth day. Discharge slight, no odor; healthy granulations lining wound. One superficial Carrel tube removed.

Seventeenth day. Remaining superficial Carrel tube removed. Pelvic tract has narrowed and shortened to a sinus about 6 centimeters in depth.

Twenty-fourth day. Wound has discharged very little since last note. Bacterial count dropped to less than 1 per field on eleventh day and Dakin's has been continued longer than would be clinically indicated in order to observe its action during the closing in of drainage tract and the bacteriological curve during this period. Bacterial count since eleventh day has never risen above 9 per field. From the eleventh to the sixteenth day counts were less than 1 to 2 per field. Wound today is perfectly clean; edges strapped together. Dakin's discontinued.

Thirtieth day. Patient discharged with firm abdominal wall. There remains a small granulating point.

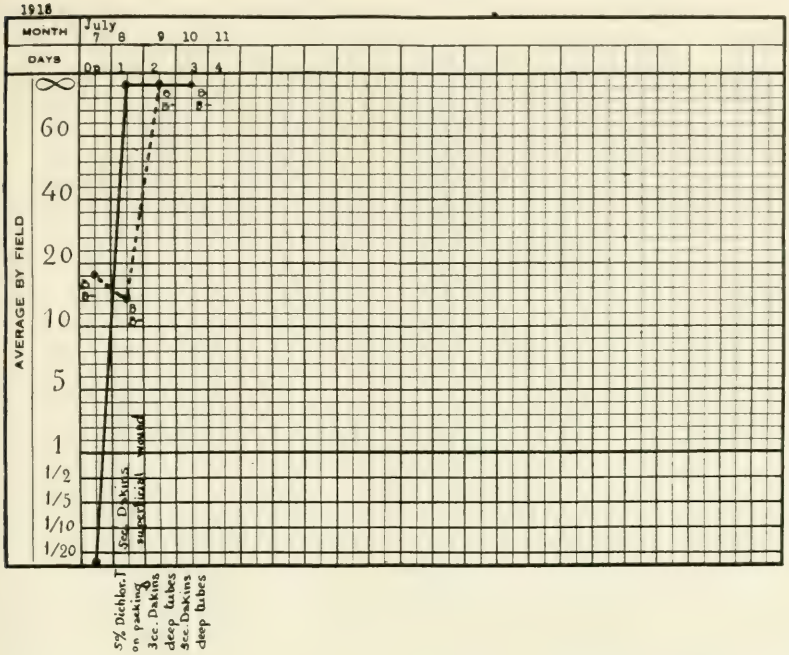

Chart 12. M. H., Ward 8, History No. 38,618. Acute appendicitis with acute local peritonitis. Perforated appendix, large amount of free, foul pus. Drains to pelvis and right lumbar gutter. ——— Superficial. – – – – Deep.

Follow-up note. 3 months: wound healed 10 days after leaving hospital; full strength regained in 3 weeks; scar is a fine, pink line; wall is firm.

Case 12. M. H. History No. 38618. American, female. Age, 50. Admitted July 7, 1918. Died July 11, 1918.

History of present attack. Onset, general abdominal pain, 48 hours ago, the distress remaining general, but tenderness chiefly in the right lower quadrant. Bowels have moved with catharsis; patient has vomited since attack.

Physical examination on admission. A very obese woman who looks acutely ill. Abdomen protuberant with much redundant fat, hanging in folds over pubes. General tenderness, but in right lower quadrant, there is a large, tender mass which seems to be fixed; connection with uterus cannot be traced. Most decided tenderness centers about McBurney's point. There is rigidity of musculature overlying the mass. Temperature 103.8°, Pulse 140, Leucocytes 7,400. Polymorphonuclears, 78 per cent.

Findings on operation. The great omentum lay in an immense œdematous mass; over the involved right lower quadrant, there was a pad of necrotic omental tissue on its free lower border in contact with the appendix. The omentum measured fully 5 centimeters in thickness in some portions. Considerable grayish, colon-smelling pus was present and poorly, if at all localized. The appendix lay along the iliac vessels attached by a very œdematous meso-appendix under the ileum. The mid-portion of the appendix was gangrenous and there was a large slit-like perforation about 0.6 centimeters in length in the center of the gray necrotic wall. Wall of cæcum and contacting loops of the small intestine was covered by a gray, fibrinous, purulent exudate.

Procedure. Ten centimeters right rectus incision. On opening the peritoneum the exudate was removed by suction; the omentum drawn outward on the abdominal wall and appendix located and removed in the usual manner, stump being inverted and site closed by purse-string of Pagenstecher, reinforced by plain gut. Double drainage tubes, one fenestrated and containing gauze packing; the other non-fenestrated, placed to the depth of the pelvis and to the right lumbar gutter.

Peritoneum closed by continuous plain gut; anterior sheath by interrupted plain gut; the skin, including the anterior rectus sheath by interrupted silkworm gut; Carrel tubes placed along the suture line in the anterior rectus sheath. Spaces between the drainage tubes not packed. One per cent formalin, wet dressing applied. Dakin's solution not to be injected into the superficial wound until after 24 hours.

Pathological report No. 21506 Gross. Specimen consists of a mass of tissue composed of an appendix and adherent omentum measuring 8½ by 3 centimeters at the widest point. The appendix itself has the tip buried in the surrounding fat and is 7 centimeters long, 1 centimeter at the base and 2½ centimeters in diameter at the tip, where there is considerable enlargement. The peritoneal coat is roughened and covered with a considerable amount of thick fibrin. The color of the appendix is a mottled greenish brown. At a point 3 centimeters from tip there is a perforation ½ centimeter in diameter. Section near the base shows great thickening of the wall; the lumen is patent and easily admits the tip of a large probe. Section through the bulbous tip shows extreme thickening and discoloration of the wall, the latter being of a dark greenish color with a red mottling. The lumen at this point is 1 centimeter in diameter and is completely filled by a large acalith which contains in its center a small mass of bony, hard consistency and irregular borders. A perforation extends from the lumen through the wall and peritoneum.

Microscopic. The mucous membrane is in part absent, the glands which remain, however, are arranged in regular order. The submucosa is greatly thickened and infiltrated with round cells. There is much hæmorrhage and œdema throughout this layer. The muscularis is also infiltrated with round cells and to the outer side of this layer there is a considerable amount of fibrin, containing in its meshes numerous lymphocytes and polymorphonuclears. Section from the point of perforation shows no evidence of mucosa. The submucosa is hæmorrhagic and closely infiltrated with mononuclear and polynuclear leucocytes. The regular arrangement of muscularis is lost and between the separate strands of muscle are many closely packed polynuclear leucocytes.

Bacteriological report. Peritoneal exudate: smear, streptococcus: culture, bacillus coli communis.

Postoperative care of wound. First day. Dressing saturated with thin, purulent exudate. The packing in the tubes has an "illuminating gas" smell. Five per cent dichloramine-T packing introduced into fenestrated tubes and about 2 cubic centimeters dropped into the other tubes. Five cubic centimeters of Dakin's ordered in the superficial tubes. Vaseline packing inserted in the angles between the drainage tubes to prevent Dakin's entering the peritoneal cavity. Patient's general condition fair.

Second day. Dressing saturated with light brown exudate. The packing from the drainage tubes has an excessively foul, colon odor. Wound edges show superficial necrosis from tight sutures above and below drains. The non-fenestrated tubes removed with ease and fenestrated tubes loosened. Catheters introduced and trial injections returned freely both within and about the tubes. Three cubic centimeters of Dakin's ordered in each deep tube; five cubic centimeters superficial.

Third day. Moderate amount of discharge having strong colon odor. Trial irrigation with Dakin's returned freely; amount increased to five cubic centimeters in the deep tubes. Upper and lower angles of wound appear firm. No redness or tenderness. Patient's condition remains fair. Temperature still above 101°. Pulse 100 to 120. Abdominal condition, however, seems to be getting under control as patient is having good returns from the colon irrigations, indicating returning bowel function.

Fourth day. Patient's temperature has risen to 104.4°; pulse 136; respiration 24. She is restless, irrational, face extremely flushed; fine, moist crepitant râles heard over both bases; no increase in voice or breath sounds; no dullness. Condition of wound shows some redness along the incision but no wound tenderness. Dakin's returning freely within the drainage tubes. About 4 hours before death, the patient became very dyspnœic and cyanotic with irregular heart action, suggesting a possible pulmonary embolus. Death occurred about 102 hours after operation. Autopsy was refused.

Case 13. M. C. History No. 38690. American, female. Age 18. Admitted July 15, 1918. Discharged August 12, 1918.

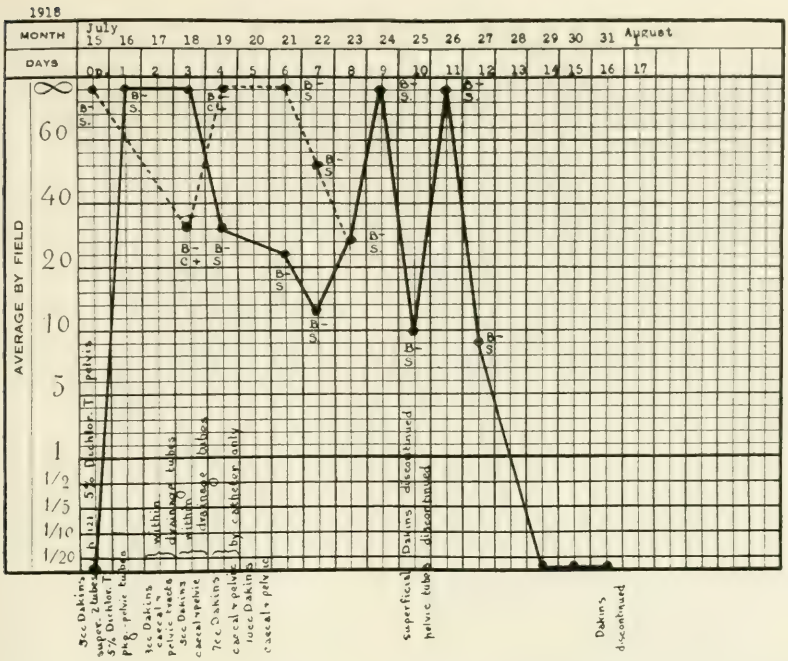

Chart 13. M. C., Ward 8, History No. 38,690. Acute appendicitis with retrocolic abscess. Drains to pelvis and cæcal region. ——— Superficial. – – – – Pelvic.

History of present illness. Six days before admission following the taking of a large dose of an emmenagogue patient was seized with general cramps. Three days later she took castor oil, which resulted in free evacuation of the bowel, but pain, instead of being relieved, was increased, and gradually localized in the right lower quadrant.

Physical examination on admission. Abdomen moves freely with respiration; there is a distinct area of rigidity in the right lower quadrant, together with acute tenderness, which is most decided just above Poupart's ligament at the junction of the middle and outer third. Temperature 101.2°. Pulse 120. Leucocytes 28,000. Polymorphonuclears, 91 per cent.

Findings at operation. Properitoneal tissue œdematous; moderate amount of slightly turbid, free, peritoneal exudate. Appendix retroperitoneal, surrounded by a small amount of pus and two fæcaliths were lying free. The appendix was very necrotic; its mesentery œdematous and friable.

Procedure. Ten centimeters oblique incision in the right lower quadrant. Intermuscular approach to the peritoneum; Weir extension. Cæcum was mobilized, appendix removed in the usual manner, the stump being doubly tied; mucosa cauterized and no inversion attempted. Large fenestrated, soft rubber drainage tube, containing gauze packing, placed to the pelvis and a double drainage tube, the ends of which were held by a suture of plain gut, inserted to the bed of the appendix beneath the cæcum. One arm of this double drainage tube was similar to that placed to the pelvis, the other was a simple closed tube. Wound closed by continuous sutures of plain gut in the peritoneum; interrupted plain gut in the muscles; wound was then washed out with Dakin's solution and aponeurosis approximated by continuous plain gut; skin and subcutaneous tissue being approximated at either end by interrupted silkworm-gut sutures. Two 5-centimeter Carrel tubes placed in the subcutaneous space along sutured aponeurosis. Three small strips of vaseline gauze introduced into the angles formed by the drainage tubes: separation type of dressings.

Pathological report No. 21535. Gross. Specimen is an appendix, 6 by 1 centimeters. The appendix is markedly discolored being of a mottled brownish green

color and its peritoneal coat is dull and covered with a considerable amount of fibrin. There is marked clubbing at the tip. At a point 2 centimeters from the base, there is a perforation, 1 by 1 centimeter and another about the same size ½ centimeter nearer the tip. The mesentery is attached throughout the outer two-thirds and is well supplied with fat, and is slightly bound down by fibrous adhesions. There is extreme congestion of the peritoneum. The lumen is patent. On section the wall is moderately thickened and there is considerable hæmorrhage into the wall at a point opposite the attachment of the mesentery. The lumen contains a small amount of firm, fæcal material. A second specimen is a fæcalith, 1½ by ¾ centimeters and is composed of firm, pasty material. A third specimen is a bit of tissue, 1½ by 2 centimeters.

Microscopic. The mucosa is almost totally absent; the submucosa is greatly thickened and œdematous and infiltrated with polynuclears and at numerous points there are areas of hæmorrhage. The muscularis is intact throughout the circumference of the appendix. This layer is closely infiltrated with polynuclear cells and its strands are at many points separated by hæmorrhage. Adjoining the appendix there is an area of mesentery closely infiltrated with round cells, and also showing a considerable amount of hæmorrhage.

Bacteriological report. Culture of peritoneal fluid: sterile. Culture of appendix abscess: bacillus coli communior.

Postoperative care of wound. Injections of 5 cubic centimeters of Dakin's fluid were begun through the two superficial Carrel tubes at the time of operation.

Twelve hours postoperative. Moderate amount of discharge of thin hæmorrhagic character on both layers of dressings. Packing from pelvic tube removed, saturated with thin, sulphurous smelling exudate. Five per cent dichloramine-T packing introduced into this tube.

First day. Thirty-six hours postoperative. Very slight amount of discharge from the peritoneal region. The gauze in contact with the wound contained a moderate amount of discharge, slightly brownish in color and odorless. Pelvic tube loosened and shortened about ¼ inch. Packing removed and replaced by fresh 5 per cent dichloramine-T packing. Tubes to cæcal region not disturbed.

Second day. Discharge from pelvic tube dark brown and serous in character. Smaller fenestrated tube inserted within the large pelvic tube and the original tube was then withdrawn over it. The closed tube to the cæcum was also removed and the remaining fenestrated tube loosened. Test injection with saline returned freely within deep tube. Instillation catheters placed to the depth of each tube and 3 cubic centimeters of Dakin's fluid ordered every 2 hours. The superficial wound was showing no redness.

Third day. Arrangement of tubes not disturbed. Dakin's fluid increased to 5 cubic centimeters.

Fourth day. There is a slight colon odor to the discharge. Both drainage tubes removed, leaving catheters in place. Dakin's fluid increased to 7 cubic centimeters in the deep tracts.

Fifth day. Moderate amount of discharge having very slight odor; slight redness about stitches. Sutures removed and wound strapped at upper and lower angles. Dakin's increased to 10 cubic centimeters.

Seventh day. Considerable discharge having a colon odor. The superficial Carrel tube to the lower angle of the wound removed. Irrigation of deep tracts with considerable return of purulent material but no slough.

Tenth day. Wound appears clean, lined by healthy red granulations. Pelvic tract has filled in to such an extent that catheter could no longer be inserted. The remaining superficial Carrel tubes removed.

Fourteenth day. Discharge very slight; sinus tract about 4 centimeters in depth; wound strapped.

Sixteenth day. Dakin's discontinued; small rubber tissue drain; wound strapped.

Nineteenth day. Sinus about 2 centimeters in depth; discharge has practically ceased; epithelium extending down into the sinus.

Twenty-sixth day. Sinus about 2 centimeters in depth and about 0.5 centimeter in diameter at the surface. Abdominal wall firm. Patient is in excellent general condition.

Follow-up note. 3 and 6 months:- general condition excellent; abdominal wall is firm at the site of scar.

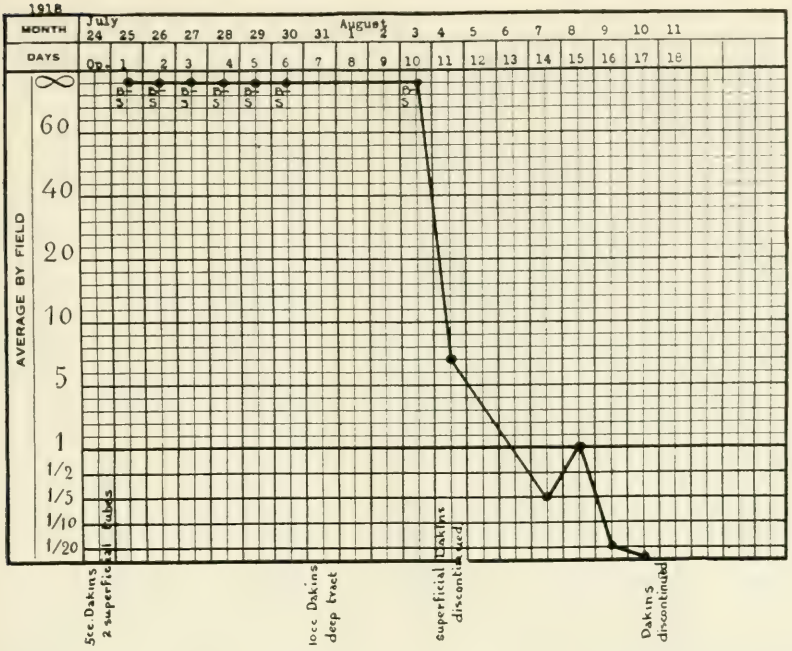

Chart 14. M. B., Ward 8, History No. 38,761. Acute appendicitis with retrocolic abscess. Drain to right lumbar gutter.

Case 14. History No. 38761. M. B. American female. Age 16. Admitted July 23, 1918. Discharged August 17, 1918.

History of present illness. Onset of general abdominal pain, with nausea and vomiting 4 days before admission. Pain localized in right lower quadrant after 2 days. Has been steadily increasing in severity; patient has had fever and chills, and continued vomiting.

Physical examination on admission. Patient appears acutely ill. She is apparently suffering great pain, lying in bed with legs drawn up; abdomen is held rigidly, moves very slightly with respiration. There is board-like rigidity in all quadrants, but more marked on the right than left. Rebound tenderness throughout. There is no especial localization. Temperature 101.8°. Pulse 116. White blood cells, 20,000. Polymorphonuclears, 89 per cent.

Findings at operation. Very small amount of free fluid; appendix retrocæcal from its midpoint to the tip; appendix was retroperitoneal. This retroperitoneal portion was necrotic and surrounded by a small amount of pus. Mesentery friable and necrotic.

Procedure. Eight centimeters oblique incision, right lower quadrant, intermuscular approach to peritoneum with Weir extension. Cæcum mobilized; appendix removed in the usual manner; the stump being inverted and site closed by a purse-string of Pagenstecher, reinforced with plain gut. A double rubber tube of the Blake type, one arm containing a strip of gauze, placed to the lumbar gutter at the site of the appendix. Peritoneum closed with continuous plain gut; muscles with interrupted plain; aponeurosis with continuous plain; skin and subcutaneous tissues with interrupted silkworm gut. Wound sponged out with Dakin's fluid during suture. One Carrel tube placed along the sutured aponeurosis of the upper portion of the wound. Drains emerged from the lower angle of the wound, so no Carrel tube was placed in this area. Separation type of dressing.

Pathological report No. 21580. Gross. Specimen is an appendix, 7 by 1 by 1 centimeters. The surface is covered with fibrin shreds and appears hæmorrhagic. The contour is very irregular, showing a curious oblique constriction near the middle, apparently not an artefact. Two centimeters from the tip is an area of necrotic

tissue in the center of which there appears to be a small perforation. On section the walls are greatly thickened although the lumen is patent and contains débris.

Microscopic. Section through the necrotic area shows the structure greatly disorganized and scarcely to be recognized as an appendix. The serosa cannot definitely be made out, but there are large areas apparently consisting of fibrin, thickly infiltrated with polymorphonuclears. The blood vessels are dilated and the walls appear thickened. The lymphoid tissue is much disorganized and shows no follicles.

Bacteriological report. Smears show gram negative bacilli and gram positive cocci.

Postoperative care of wound. First day. Dressing saturated with thin exudate; wound dressed as at operation.

Second day. Slight amount of discharge; no redness, tenderness or induration of wound; wick removed from drain, and fresh one inserted.

Third day. Considerable discharge with a marked colon odor; no redness about sutures; wick removed and fresh one inserted; patient has had 5 cubic centimeters of Dakin's fluid in superficial wound every 2 hours since operation, but no antiseptic has been introduced into the deep drainage tract.

Fifth day. Moderate amount of discharge with colon odor, three upper silkworm gut sutures removed; wound healing firmly; wick removed and replaced. No antiseptic has been used in the deep tract.

Seventh day. Considerable foul-smelling pus on dressing; the double drainage tube removed; wound irrigated with saline; considerable necrotic material returning. A thin-walled fenestrated drainage tube, about 3 inches in length inserted into the upper part of tract and a catheter introduced alongside. Ten cubic centimeters of Dakin's ordered every 2 hours in the deep tract.

Ninth day. Wound irrigated, considerable yellow necrotic return.

Tenth day. Drainage tube removed, leaving catheter in place in the deep tract. There is still a considerable amount of necrotic material obtained on irrigation.

Eleventh day. Superficial Dakin's tube discontinued. Wound lined by clean, healthy granulations.

Seventeenth day. Discharge slight and odorless. Tract about 6 centimeters in depth.

Eighteenth day. Tract has closed in to a narrow sinus; organisms have been below 1 per field for the past 4 days; Dakin's discontinued. Small rubber tissue drain inserted and wound strapped.

Twenty-third day. Abdominal wall seems firm; there is still a small granulating area at lower angle of wound; discharge negligible. Patient up and about.

Follow-up note. 3 months: general and local condition excellent; wall is firm at site of scar.

Case 15. C. V. History No. 39250. Male. Age 39. Admitted September 22, 1918. Discharged October 12, 1918.

History of present illness. Onset of general abdominal pain, 3 days ago; vomited twice; has kept about on feet until time of admission.

Physical examination on admission. Respiratory movements of abdomen restricted; sense of resistance in lower abdomen but not true rigidity; palpable mass in right lower quadrant from level of McBurney's point to Poupart's ligament. Rebound tenderness greater in left than right side. Temperature 101.2°. Pulse 116. White blood cells 18,000. Polymorphonuclears 92 per cent.

Findings at operation. Considerable cellulitis of abdominal wall; free cloudy fluid in large quantity with peculiar odor, not typically colon. Numerous fibrin flakes in the exudate. Subcæcal abscess containing 1½ ounces of thick, colon-smelling pus. Appendix gangrenous and perforated in two places.

Procedure. Oblique intermuscular with Weir extension; exudate removed by suction; abscess broken into and pus evacuated by suction; appendix removed in usual manner. Stump inverted and site reinforced. Double tube of the usual type, containing dichloramine-T tape inserted to the abscess cavity and single fenestrated tube inserted to the right lumbar gutter. Abdominal wall closed in layers, wound being washed with Dakin's solution; Carrel tubes placed along aponeurosis; skin sutured loosely with interrupted silkworm gut. Vaseline strips; separation dressing. Five cubic centimeters Dakin's solution ordered every 2 hours in superficial tubes.

Pathological report. Gross. Specimen is an appendix 10 centimeters in length and 0.8 to 1.3 centimeters in diameter. It is discolored throughout, with a very irregular surface. In the terminal third the surface is covered by a thick, smooth

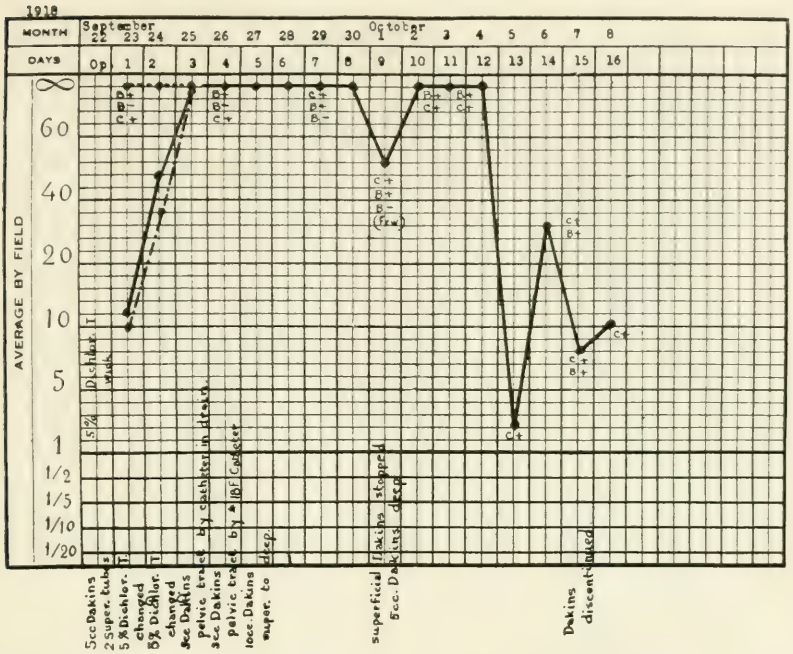

Chart 15. C. V., Ward 10, History No. 39,250. Acute appendicitis with pelvic abscess. Drains to pelvis and right lumbar gutter. One tract not treated. ——— Superficial —·—·—·— Right lumbar gutter. – – – – Pelvic.

layer of fibrinopurulent exudate. In its middle third on its concave border, there is a perforation 0.6 centimeter in diameter. There is a fæcalith of ovoid shape, 1 by .5 centimeter which has apparently been extruded from the lumen. Only a small amount of meso-appendix is attached. The remaining portion is very œdematous and infiltrated. On cross section, the terminal third shows a small lumen and a very œdematous and infiltrated wall throughout. Extravasations of blood are distinctly prominent. In the proximal third the wall is likewise thickened, but the inflammatory exudate is not well defined. Section at the level of the perforation shows an almost total necrosis of the wall.

Microscopic. Section through the proximal third shows the mucosa fairly well preserved. There is distinct polymorphonuclear infiltration of the remaining coats and there is fibrin upon the serosal surface. Section through the terminal third shows a lumen occupied by a large massive fibrinopurulent membrane. The mucosa is almost completely destroyed. The lymphoid elements of the submucosa and the structures of the remaining coats have likewise been destroyed. Polynuclear infiltration with extensive œdema and round-cell infiltration with thick fibrinopurulent exudate upon the peritoneal surface is present. Section at the site of perforation shows necrosis of the wall.

Bacteriological report. Culture of exudate: bacillus pyocyaneus. Culture pus: bacillus pyocyaneus and streptococcus.

Postoperative treatment of wound. Patient did not show evidence of through-and-through peristalsis until the fourth day. He was treated by repeated lavage; Murphy drip; colon irrigations; hypodermic clyses; and intravenous infusions of saline and glucose, fluids being withheld by mouth until the fourth day.

Twenty hours. Considerable light brownish discharge from deep tracts, having an odor resembling asafœtida. On withdrawing wick from tube to lumbar gutter, about 1½ ounces of brown serous fluid issued under pressure. Tapes removed from drainage tube and fresh dichloramine-T wicks replaced.

Forty hours. Considerable light brown, colon exudate from deep pelvic tract. That from lumbar gutter has a very faint odor. Closed tube to pelvis removed;

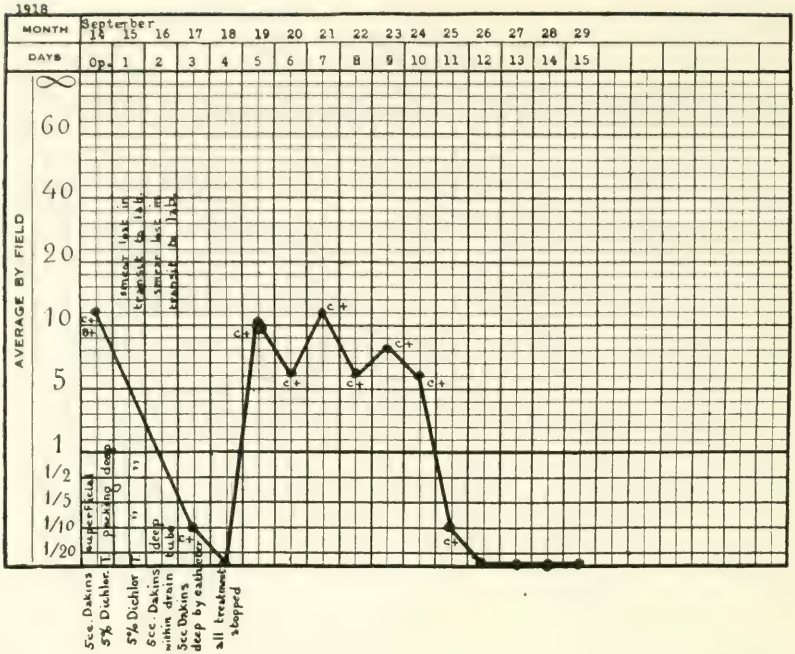

Chart 16. J. H., Ward 10, History No. 39,197. Acute appendicitis with peritoneal abscess, pelvic. Drains to pelvis.

fenestrated tube loosened and a fresh dichloramine-T strip introduced. No. 18 French catheter introduced through fenestrated tube to right lumbar gutter and tube then slipped out.

Third day. No. 18 French catheter introduced to depths of pelvic drainage tube, which was then removed. After trial injection with saline, 5 cubic centimeters of Dakin's introduced without pain. Five cubic centimeters of Dakin's ordered every 2 hours.

Fourth day. Slight amount brownish, faintly colon discharge. Some redness about stitches. Catheter to lumbar region shortened about 1 centimeter.

Fifth day. Catheter to right lumbar gutter shortened 2 centimeters and 10 cubic centimeters of Dakin's ordered to pelvic tract.

Seventh day. Moderate amount of colon discharge; small shred of slough removed at edge of aponeurosis; catheter to right lumbar gutter replaced by No. 10 French. Irrigation of this tract did not return freely. No Dakin's has or will be used in this tract, owing to its tortuosity.

Eighth day. Catheter to right lumbar gutter out; interior wound now lined by bright red granulations.

Tenth day. Several small catgut knots on dressing but no slough. Discharge has slight odor; superficial Carrel tubes out. No. 14 French catheter to pelvic tract. Five cubic centimeters of Dakin's ordered.

Eleventh day. Small piece of slough removed, apparently from tract to lumbar gutter.

Fifteenth day. Slight mucoid discharge; no odor; bacterial count 2 per field; Dakin's discontinued; wound strapped.

Eighteenth day. Granulations flush with skin surface; no discharge.

Twentieth day. Tiny granulating spot.

CASE 16. J. H. History No. 39197. Male. Age 14. Admitted September 14, 1918. Discharged October 7, 1918.

History of present illness. Onset of general abdominal pain 3 days before admission. Has not localized to any extent. Tenderness greatest in right lower quadrant. No nausea or vomiting.

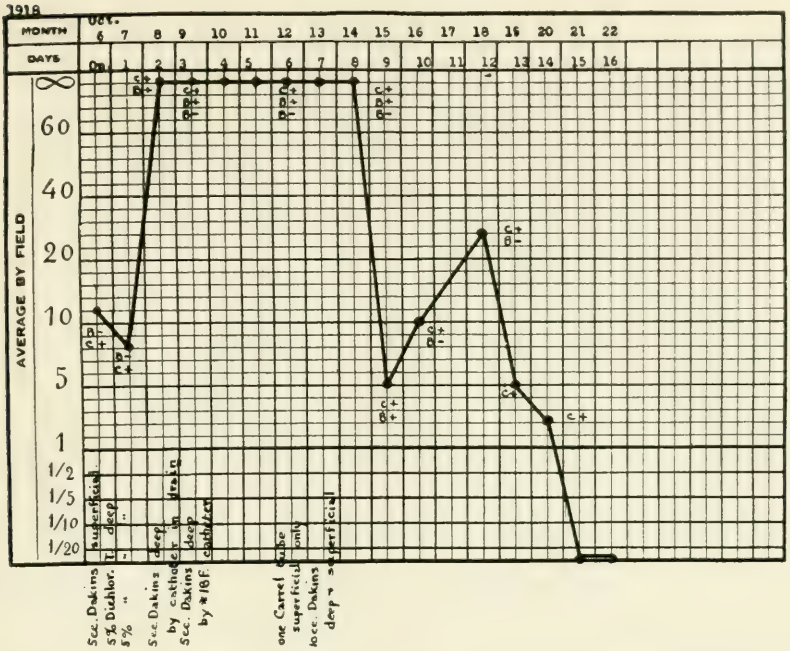

Chart 17. J. A., Ward 8, History No. 39,375. Appendicitis with peritoneal abscess, subcæcal. Drains to pelvis.

Physical examination on admission. Temperature 101.6°. Pulse 122. On abdominal examination, a distinct tender mass, centering about the anterior-superior spine of the ileum on the right side was felt. Same tender mass palpable by rectal examination. White blood cells, 24,500. Polymorphonuclears, 90 per cent.

Findings at operation. Appendix surrounded by omentum; completely walled off by fresh fibrinous adhesions; small amount of pus surrounding tip of appendix, which lay in pelvic position. Appendix gangrenous.

Procedure. Oblique intermuscular incision; appendix removed in the usual manner. Stump inverted by purse-string, which was reinforced. Double drainage tubes placed to pelvic region, the tips being united by a loop of plain gut. Abdominal wall closed in layers; two Carrel tubes along the sutured aponeurosis. Five per cent dichloramine-T packing in one of the drainage tubes. Vaseline strips and separation dressing. Five cubic centimeters Dakin's solution ordered every 2 hours in superficial tubes.

Bacteriological report. Bacillus coli communis; streptococcus.

Pathological Report. Gross. Specimen is an appendix, 3 by 1 centimeters which has been torn open in its middle half. The surface is mottled and is covered with a thick fibrinopurulent exudate. The mesentery is very narrow and appears densely infiltrated. On section, the wall is greatly thickened and the lumen is represented by a mere cleft. There is decided œdema especially noticeable in the subserosa where there has also been an extravasation of blood.

Microscopic. The wall of the appendix is enormously thickened. The mucosa has undergone a partial destruction. There is an invasion of all coats by polynuclears especially pronounced in the loose subserosal plane. In some sectors of this plane there is pronounced extravasation of red blood cells. There is a very thick, fibrinopurulent exudate, in one place almost the width of a high power field, upon the serosal surface. The portion corresponding to the meso appendix shows extensive infiltration, œdema, and fibrinous deposits.

Postoperative treatment of wound. Eighteen hours postoperative. Slight, serous, odorless discharge; dichloramine-T packing removed and replaced.

At 44 hours. Closed drainage tube removed. Found plugged at the end with a clot of fibrin. Fenestrated tube loosened and shortened. No. 10 French catheter

to the depth of the remaining tube. Trial injection with saline returned within and about tube. Five cubic centimeters of Dakin's injected without pain and ordered every 2 hours.

Third day. No gross suppuration; firm white fibrin lining wound. No. 18 French catheter inserted. Drainage tube removed.

Fourth day. Exudate slight, slimy, with chlorine odor. Smear counted on ward, no organisms. All tubes removed and treatment stopped. Michel clips applied. Dry dressing.

Seventh day. Slight amount of discharge with faint odor. Bacterial count has risen to eleven per field. Michel clips removed.

Ninth day. There has been some separation of wound edges. The edge of aponeurosis is visible; appears white.

Thirteenth day. About 1 drachm creamy, light grey, odorless exudate expressed. Wound lined throughout by bright granulations.

Sixteenth day. Wound closing rapidly. Discharge negligible. Patient up and walking.

Twenty-third day. Wound presents a cleft 1 centimeter in length and ½ centimeter in depth. Granulations sluggish. Treatment with Dakin s solution for 2 days longer in the beginning would have probably saved time in healing.

Follow-up note. 2 months: general condition excellent. Scar is a wide, pink line; wall is firm.

Case 17. J. A. History No. 39375. Age 28. Italian female. Admitted October 5, 1918. Discharged October 24, 1918.

History of present attack. Onset of acute abdominal pain 4 days before admission; first in epigastrium, then over entire abdomen and finally localizing in the right lower quadrant where it has remained constant and severe. Vomiting occurred 6 hours after onset of pain. Bowels have moved by catharsis several times.

Abdominal examination. Abdomen not distended, acute tenderness confined to right lower quadrant in area immediately above Poupart's ligament. Reflex muscle spasm present over the tender area. By vagina, a very tender, irregular mass, 4 to 5 centimeters in diameter is present in the right fornix. Temperature on admission 102.4°. Pulse 120. White blood cells 9,000. Polymorphonuclears 76 per cent.

Operation. October 6, 1918. Incision 8 centimeters right rectus through the muscle.

Findings. The appendix pelvis in position, surrounded by adherent omentum; small localized abscess posterior to cæcum; pus was creamy, white, and odorless; the omentum attached to appendix was extremely œdematous, being fully 2 centimeters in thickness and its adhesions to the appendix were organized. Small amount of clear, free fluid present; there was slight involvement of the serosa of adjacent intestinal coils.

Procedure. Appendix removed in the usual manner and abscess evacuated; the stump of the appendix was inverted and site reinforced; double drainage tube, the tips united by a loop of catgut and the fenestrated arm packed lightly with dichloramine-T gauze placed to the pelvis; the abdominal wall closed in the usual manner with the exception of a few, interrupted, plain, gut sutures in the superficial fascia. Two Carrel tubes placed along the anterior rectus sheath. Vaseline strips inserted between the drainage tubes. Separation type of dressing.

Pathological report. Gross. Specimen is an irregular mass, 10 by 3½ by 2 centimeters which has the appearance of a much diseased and distorted appendix. The surface although relatively smooth has in places definite fibrin deposit and the substance of the mass appears very friable. Near the center is a dark blue area where the wall appears very thin and wrinkled. There are several superficial hæmorrhagic areas and the entire mass is dark colored. Section through the thickest part shows the lumen contains a fæcalith, 1 by ½ by ½ centimeter. The walls are very thick and hæmorrhagic and the mucosa appears necrotic. At one portion the wall is thin. Section through the above-mentioned dark area discloses a thin-walled cavity containing fæcal débris.

Microscopic. There is an extensive invasion of the walls of the appendix by phagocytes. The mucous membrane is missing. The mesentery of the appendix is much enlarged from œdema.

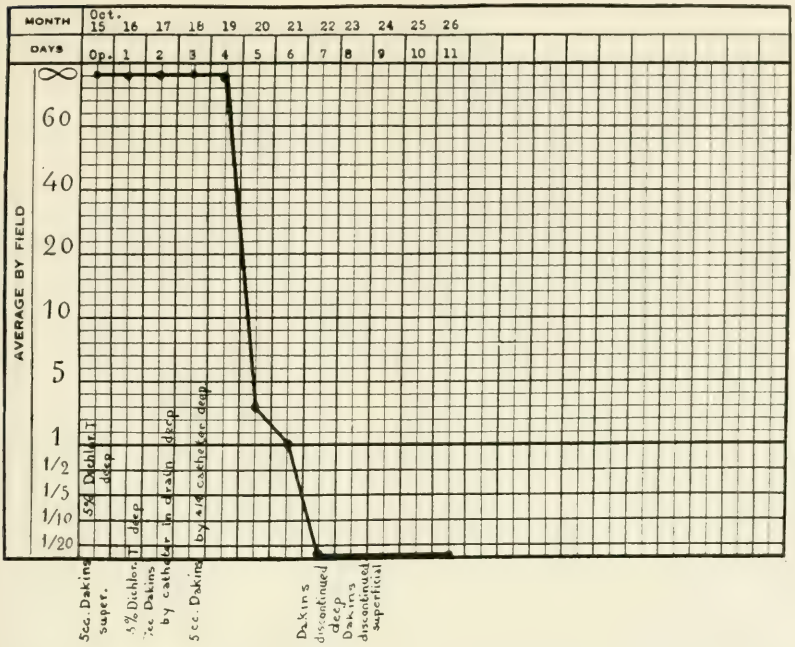

Chart 18. M. R., Ward 10, History No. 39,542. Acute appendicitis with peritoneal abscess, mesocæcal. Drains to abscess cavity.

Bacteriological report. Bacillus coli communior; streptococcus probably present.

Postoperative care of wound. First day. Profuse light pinkish discharge from peritoneal cavity; dichloramine-T strip removed from pelvic tube, another reinserted and 2 cubic centimeters of 5 per cent dichloramine-T instilled in closed tube. Patient has been receiving 5 cubic centimeters of Dakin's solution every 2 hours in each superficial Carrel tube.

Second day. Patient in excellent condition; slight amount of thin, pinkish exudate in the deep tube. Closed tube removed; fenestrated tube loosened and shortened. The catheter inserted to the depths of remaining tube, trial injection of saline returned about the tube first. There is a good straight drainage tract, about 8 centimeters in depth. Five cubic centimeters of Dakin's injected without reaction and 5 cubic centimeters ordered deep and superficial every 2 hours.

Third day. No redness about wound; discharge has a slight colon odor. No. 18 French catheter introduced to the pelvis and fenestrated tube removed. Dakin's continued in 5 cubic centimeter amounts in the two tubes and catheter.

Fifth day. A small amount of colon smelling discharge. No. 14 catheter introduced, replacing No. 18 French. No inflammatory reaction about sutures.

Sixth day. Silkworm sutures at angle removed; also Carrel tube to lower angle

Seventh day. Moderate amount of brownish colon exudate. Few pieces of whitish slough on irrigation; deep Dakin's, 10 cubic centimeters every 2 hours.

Eighth day. Several sloughs removed, apparently from anterior rectus sheath.

Ninth day. Considerable purulent discharge, but less offensive. No. 10 French catheter introduced. Wound lined by bright granulations.

Twelfth day. Slight discharge, no odor.

Fifteenth day. Wound healed except at site of catheter, which extends downward about 3 centimeters. Discharge has ceased. Dakin's discontinued.

Eighteenth day. Abdominal wall firm; tiny sinus at site of drainage; no discharge.

Follow-up note. 2 months: resumed work 3 weeks after leaving hospital. General condition excellent. Scar is a narrow, pink line; abdominal wall is firm.

Case 18. M. R. History No. 39542. Male. Age 7. Admitted October 15, 1918. Discharged November 2, 1918.

History of present attack. History of recent pneumonia 15 days before admission. On recovering from pneumonia, about a week before admission, developed pain and a tender mass in right lower abdomen. Increasing fever during past 3 days.

Physical examination on admission. Child acutely ill; large tender mass in right lower abdomen; with overlying tenderness and reflex muscle spasm. Temperature on admission 103°, pulse 140; white blood cells, 31,500. Polymorphonuclears 74 per cent.

Operation, October 15. Incision intermuscular.

Findings. A moderate amount of turbid, foul-smelling exudate in right lumbar gutter and pelvis. A large abscess walled off by omentum and adherent coils of intestine lay beneath the lower part of the right rectus muscle extending well over to midline; abscess contained dark grey, foul-smelling pus and the sloughed-off appendix. Wall of abscess cavity was lined by slough and at one point in its lower portion the stump of appendix could be palpated.

Procedure. On opening the peritoneal cavity, exudate was removed by suction and protecting pads introduced. Abscess was then opened and evacuated by suction and further cleansed by sponging. Double drainage tube of the usual type introduced. Small rubber tube placed to the depths of pelvis and rubber tissue drain to the right lumbar gutter. The planes of abdominal wall were approximated loosely about tubes by interrupted plain gut and angles of skin by interrupted silkworm-gut. Silkworm-gut suture placed in mid-portion of wound and left untied. Carrel tubes placed along aponeurosis and separation type of dressing applied.

Pathological report. Gross. Specimen is a small piece of tissue, 2½ by 1 centimeters. It consists of a loose, thin membrane surrounding an oval brown mass which seems to be inspissated fæces. On section, most of the diameter of the specimen consists of fæcal material. Normal coats of the appendix not recognized.

Microscopic. Shows only fibrin and necrotic tissue of indeterminable type.

Bacteriological report. Bacillus coli communis.

Postoperative care of wound. First day. Considerable amount of thin bloody discharge from deep portion of wound dichloramine-T strip removed and replaced; separation type of dressings applied. Patient has received 5 cubic centimeters of Dakin's every 2 hours through the two superficial Carrel tubes. Eleven p. m. of first day: Patient restless; passed hand under dressings and partially dislodged all tubes. Thereupon the closed tube was removed, the fenestrated tube to the abscess cavity cleansed and replaced; rubber tube to pelvis and rubber tissue drain to right lumbar gutter shortened.

Second day. No. 10 French catheter introduced to depth of fenestrated tube and 5 cubic centimeters of Dakin's ordered every 2 hours, intra-abdominally. Thin colon smelling discharge.

Third day. No. 12 French catheter to abscess cavity, fenestrated tube out. Tube to pelvis and rubber tissue drain to right lumbar gutter removed. Discharge light brown with colon odor.

Fifth day. Profuse colon discharge, 10 cubic centimeters of Dakin's ordered in catheter and both superficial Carrel tubes.

Sixth day. Wound lined by pink granulations; the colon odor to discharge has practically disappeared.

Seventh day. Discharge from deep tract has ceased and sinus is apparently obliterated, catheter having been forced out. There has been some gaping of the skin. Dakin's continued superficially. Coaptation adhesive applied.

Eighth day. Sutures removed from angle and suture in mid-part of wound tied. Dakin's discontinued. Bacterial count shows no organism.

Tenth day. Suture found broken and removed. Wound cleansed and adhesive strapping applied. Patient showing rise in temperature, 103.6°, but does not appear ill. No indication of outlying pocket of pus.

Twelfth day. Temperature again normal; slight serous discharge from wound.

Fifteenth day. Wound is shallow, granulating sinus, 2½ centimeters in length. Patient allowed up.

Eighteenth day. Abdominal wall firm; there was a superficial granulating area 5/10 by 1 5/10 centimeters.

Follow-up note. 6 weeks: child immediately resumed full play on arriving home. There is a diffuse bulge at the site of wound; the abdominal wall feels generally thin, but no definite hernial neck made out.

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CLINICAL AND EXPERIMENTAL STUDIES ON CONGENITAL PYLORIC STENOSIS[1]

By RICHARD LEWISOHN, M.D., F.A.C.S., New York
Attending Surgeon, Beth Israel Hospital and Montefiore Home; Associate Attending Surgeon, Mount Sinai Hospital

STENOSIS of the pylorus in newborn babies is a borderline disease and its successful treatment needs the closest co-operation of the pediatrist and the surgeon. Some pediatrists have claimed that in the vast majority of cases the disease can be cured without surgical interference. On the other hand, surgeons have made the statement that congenital pyloric stenosis is a purely surgical condition, that medical treatment of these cases is not only without any value, but decidedly harmful. Both these statements are erroneous.

The attempt has been made to divide this disease into two distinct groups: (1) pylorospasm and (2), true hypertrophic pyloric stenosis. The opinion has been expressed frequently that the first group requires only medical treatment, whereas the second group requires surgical intervention. Such a division of these cases into two groups is too didactic. Holt's advice, simply to divide these cases into mild and severe cases without making an actual anatomical distinction between the two groups, is more in accordance with the clinical facts.

The cause of this disease is a malformation at birth with secondary œdema; in fact, Dent has observed a true pyloric stenosis in a seven-months' old fœtus which shows that the origin of the disease dates back to the antenatal period.

The clinical symptoms of congenital pyloric stenosis are: incessant vomiting, loss of weight and constipation, palpable tumor and visible peristalsis. In a case presenting the above signs the presence of a pyloric tumor is pathognomonic of the disease. However, in many cases the pyloric tumor is not palpable. Visible peristalsis of the stomach, loss of weight, and vomiting are sufficient clinical signs to establish the diagnosis.

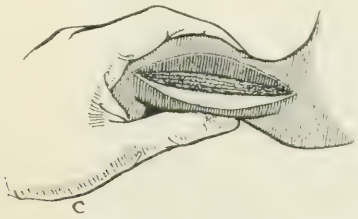

Fig. 1. Rammstedt operation (copied from Sloan).

We do not agree with the opinion expressed by some that all patients with congenital pyloric stenosis, should be immediately operated upon. The pediatrist should try to cure these cases with proper diet, paregoric, and other remedies. If all his endeavors are futile, if no improvement is observed after a few days, and if the baby continues to lose weight rapidly, the case should be treated surgically without much delay.

Seventeen cases of congenital pyloric stenosis were admitted to Dr. Koplik's Service at Mount Sinai Hospital during the last three years. Eight cases were treated medically, and nine were transferred to the Surgical Department. Of the former eight cases, one died and seven were discharged from the hospital as improved or cured. The mortality among the nine cases operated on was much higher; five were cured and four died. The fact that the severe cases with marked emaciation were subjected to operation, whereas the milder forms of this disease were treated medically, may explain the much higher mortality among the cases operated on.

Methods of operation. Until a few years ago gastro-enterostomy represented the only surgical procedure for these cases. Since then, the Rammstedt operation, published in 1913, has acquired great popularity. This operation consists of incising in a longitudinal direction the thickened and hardened pylorus through serosa and muscularis and down to the mucosa, without perforating the mucosa (Fig. 1). The division of the contracted muscular ring effects a re-establishment of the pyloric

[1]From the Laboratory for Surgical Research, College of Physicians and Surgeons, and the Surgical Service of Dr. A. A. Berg, Mount Sinai Hospital.

lumen and a disappearance of the obstructive symptoms.

This new and very ingenious operation was generally adopted and extensively used by surgeons. Downes, for instance, has reported sixty-six cases of pyloric stenosis operated on, thirty-five of which were operated on by the Rammstedt method. The mortality of his cases was 23 per cent. Gallie and Robertson have lately reported sixteen cases of Rammstedt operation with a mortality of 31 per cent.

Whether this Rammstedt operation will entirely supplant gastro-enterostomy in the surgical treatment of congenital pyloric stenosis remains to be seen. The operation, though it appears very simple and harmless, is certainly not without danger. In order to effect a cure the thickened pylorus must be divided in its whole length and thickness. If the incision fails to divide the entire thickened area from stomach to duodenum, if it is just a little too short, a cure will not be effected. If this incision is made only 1 millimeter too long on the duodenal side, there is grave danger of opening the duodenum, which is especially thin in these cases. In other words, the margin between what we must do to accomplish our object and what we must avoid to prevent serious damage, is such a narrow one that the operation cannot be regarded as free of risk or danger.

Fig. 2. Rammstedt operation upon dog, thirteen days after operation.

Experiments. The series of experiments upon dogs was performed in order to study the histological effects of the Rammstedt operation. Six specimens were examined microscopically. A period ranging between five and ninety-one days had elapsed between the time of operation and the time of autopsy.

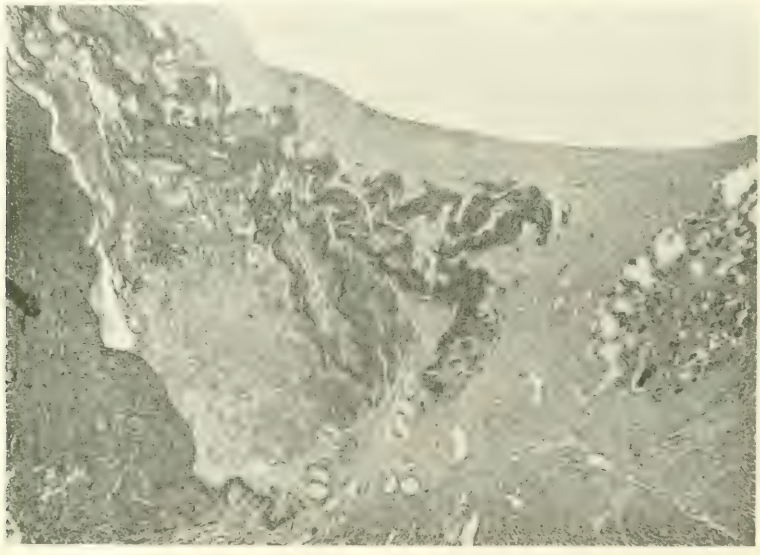

Fig. 3. Same as Figure 2, higher magnification.

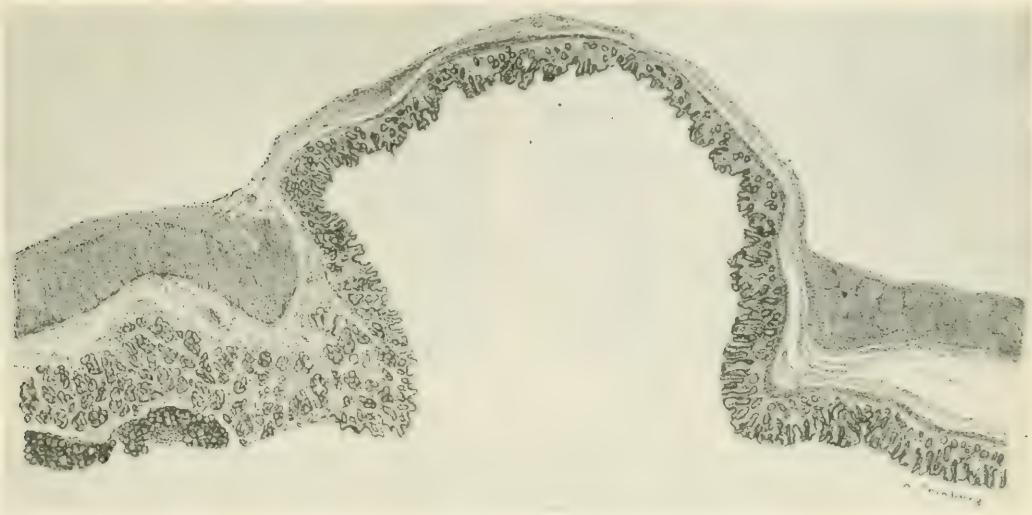

Fig. 4. Hernia of the mucous membrane, following an experimental Rammstedt operation.

Dog 280, Surgical Pathology No. 3,414. Operation, April 6, 1915. One and one-half inch longitudinal incision. Died, April 11, 1915 (peritonitis). Autopsy revealed the following: The mucosa exposed by the Rammstedt operation was gangrenous; there was no perforation. Diagnosis: gangrene of stomach mucosa, peritonitis. Microscopical examination: The cut ends of the muscle-bundles are separated from one another by a distance of 12 millimeters. The intervening space is filled with a dense blood coagulum. There are a few leucocytes, indicating the absence of infection at this point. Very little repair has taken place. At the junction of the muscularis with the blood-clot, areas of dead tissue are visible. The submucosa and mucosa are intact throughout.

Dog 359, Surgical Pathology No. 3,516. Operation, May 18, 1915: 3 centimeter longitudinal incision; four black localizing sutures. Killed, May 31, 1915. Autopsy revealed the following: The place of incision was prominent, showing a reddish protruding area, extending up to the four localizing sutures. Microscopical examination: There is a defect in the wall of the pylorus, 11 millimeters in width, extending down to the submucosa. This defect is filled with a very dense mass of fibrin with particularly thick strands. It projects as a nodule above the adjacent serosa. The repair is represented by a growth of fibroblasts in a thin film over the surface of this mass. Apparently no growth has occurred into the mass itself. A cross section of the black silk suture just beneath the serous surface at the edge of the mass shows wide separation of the fibers by connective tissue. The mucous membrane and submucosa are intact throughout (Figs. 2 and 3).

Dog 166, Surgical Pathology No. 3,311. Operation, January 19, 1915: Longitudinal incision and small cross incision. Killed, February 9, 1915. Autopsy revealed the operative field covered by adherent omentum; region of incision somewhat hardened. Microscopical examination: Cross section through the pylorus at the region of the incision; mucous membrane and submucosa are intact throughout. The inner circular layer of the muscularis appears intact. The outer layer of the muscle has almost completely disappeared and at this point the fatty vascular tissue of the omentum is attached. The omentum is also adherent to the serosa throughout the length of the section.

Dog 335, Surgical Pathology No. 3,532. Operation, May 4, 1915: typical Rammstedt operation. Killed June 8, 1915. Autopsy revealed a slight scar, 5 centimeters long in pyloric region, of whitish color. Microscopical examination: Mucosa and submucosa are intact and normal throughout. There is a complete gap in the muscularis ½ centimeter in width, filled with omentum and scar tissue, which is attached directly to the submucosa.

Dog 180, Surgical Pathology No. 3,396. Operation, February 2, 1915: 3 centimeter longitudinal incision over the pyloric region; mucosa accidentally perforated; it was closed with purse-string suture. Killed, March 30, 1915. Autopsy revealed a whitish scar, partly covered by small omental adhesion. Microscopical examination: The mucosa is intact throughout, but at the site of the incision, it is somewhat irregular and some of the glands are cystic. There is a small irregular band of scar tissue dividing both muscular layers, about 1 millimeter in width. The omentum is adherent to the external border of the scar tissue.

Dog 270, Surgical Pathology No. 3,561. Operation, March 30, 1915: Rammstedt operation. Killed, June 29, 1915. Autopsy revealed a distinct defect about the size of a pea at place of operation

Fig. 5. Case 4, baby two weeks after Rammstedt operation.

Fig. 6. Same baby, nine months later.

with hernia of the mucous membrane. Microscopical examination: There is a complete gap in the wall of the pylorus about 1 centimeter in width; projecting through this is a fold of the mucosa, which is covered throughout with fibrous submucosa. The cut ends of the muscularis are attached to the submucosa at either side of the defect (Fig. 4).

The findings can be summarized in the following manner: Following an incision of the pylorus through serosa and muscularis, there is evidently a gaping wound produced, which fills with blood-clot, to which the omentum becomes adherent. This clot is replaced by fibrous tissue, which, when it contracts, brings the cut muscle ends into such close apposition that they may only be separated by millimeters. Regeneration of the smooth muscles does not seem to occur.

Of peculiar interest is the case in which there was an eversion of the mucosa and submucosa through the defect. As no mention of a similar occurrence can be found in the literature, reasons for its occurrence are only problematical. It is possible, however, that it may have occurred very shortly after the operation was completed, due to a violent segmentation-contraction of the pyloric musculature, which may have forced a fold of mucosa and submucosa through the gaping wound. Fibrinous adhesions may then have fixed the raw submucosa to adjacent omentum (Fig. 4).

Case 8 of the series shown in chart is of sufficient interest to warrant a more detailed description. This baby was brought to the hospital with typical symptoms of pyloric stenosis. A Rammstedt operation failed to stop the vomiting. Therefore, a second laparotomy was performed eighteen days after the primary operation. In the attempt to lengthen the original incision across the pylorus the duodenum was accidentally injured. The pinhole opening in the duodenal mucosa was closed with a double purse-string suture.[1] These sutures narrowed the lumen of the duodenum to such an extent that a gastro-enterostomy was deemed necessary. The child died two days following the second operation.

A postmortem examination was performed and the stomach removed *in toto*. The specimen showed very well why the vomiting had not stopped after the first operation. The Rammstedt incision, though of sufficient length, had not divided the musculature completely, except in the very center of the incision (Fig. 7, *a*), where the mucosa was distinctly

[1] The same accident happened to me in a case operated upon in a private sanatorium and not included in the accompanying chart.

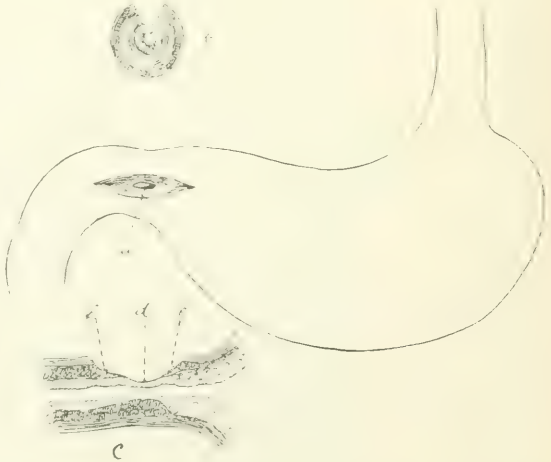

Fig. 7. Postmortem findings of Case 8. *a*, Mucosa of stomach exposed in center of Rammstedt incision; *b*, cross section through center of Rammstedt incision; *c*, longitudinal incision through pyloric region.

CASES OF PYLORIC STENOSIS OPERATED ON

Case	Date	Age	Duration of Symptoms	Operation*	Weight		Stay in Hospital	Result
					On Admission	On Discharge		
1	Dec. 1913	4 months	Since shortly after birth	Rammstedt	6 lbs. 1 oz.	8 lbs. 5 oz.	6 weeks	Cured.
2	Aug. 1914	3 months	2½ months	Rammstedt (Figs. 5 and 6)	5 lbs. 9 oz.	8 lbs. 2 oz	2 months	Cured.
3	Aug. 1914	3 months	1 month	Rammstedt (accidental opening of duodenum)	8 lbs. 14 oz.	8 lbs.	40 days	Died of marasmus; signs of stenosis persisted; no postmortem.
4	Aug. 1915	4 weeks	Shortly after birth	Gastro-enterostomy			26 days	Continuous vomiting. Exitus. Postmortem showed ulcerative process in the whole gastro-intestinal tract. Gastro-enterostomy functionating.
5	Sept. 1915	6 weeks	3 weeks	Rammstedt	5 lbs. 8 oz.	5 lbs. 13 oz.	20 days	Cured.
6	Mar. 1916	6 weeks	2 weeks	Rammstedt	6 lbs. 4 oz.	6 lbs. 14 oz.	38 days	Cured.
7	Mar. 1916	7 weeks	3 weeks	Rammstedt	6 lbs. 15 oz.	6 lbs. 12 oz.	26 days	Died. No postmortem.
8	Nov. 1916	6 weeks	3 weeks	Rammstedt; second operation 18 days after first operation: revision of Rammstedt, accidental injury of duodenum, gastro-enterostomy (see Fig. 7).				Died 22 days after first operation, 2 days after second operation.
9	Mar. 1917	4 weeks	3 weeks	Gastro-enterostomy	5 lbs. 8 oz.	6 lbs. 9 oz.	28 days	Cured.

*Operators: Drs. Lilienthal, Berg, Moschcowitz, and Lewisohn.

visible. Figure 7, *b* shows schematically a cross section through this very center. Figure 7, *c* represents a longitudinal section through the pylorus beyond the edges of the incision. It shows that the muscular layer was incompletely divided, the incision having been carried down to the mucosa in one-third of its length only.

Microscopical studies of sections removed from the center of the incision, the proximal and the distal ends respectively were in accord with the macroscopical findings. The latter two sections showed the incomplete division of the muscular layers of the stomach.

a. Cross section through center of incision. A cross section through the middle of the gaping wound in the pylorus showed that both muscle layers have been completely divided and their ends have retracted leaving a V-shaped gap. The exposed submucosa is covered with a thin layer of fibrin which extends on either side and covers the cut muscle ends. Active proliferation of fibroblasts has replaced a portion of this fibrin meshwork. There is very moderate inflammatory reaction, evidenced by the presence of a few round cells. The mucous membrane is intact (Fig. 8).

b. Cross section through proximal end of incision. Sections of the cardiac end of the wound show a similar picture, except that the inner circular layer of muscle has not been completely divided and the fibrin meshwork at the bottom of the wound lies upon it instead of upon the submucosa (Fig. 9).

c. Cross section through distal end of incision (Fig. 10). Cross section through the duodenal end of the wound shows that the muscularis is almost intact, only a small defect being present in the outer layers, the surface of which is covered with a coagulum, among the fibers of which many young connective-tissue cells can be seen.

These sections demonstrate very plainly the incomplete division of the muscularis. In order to avoid the danger of perforation, the incision had not been uniform in depth and the stenosis was thus not completely relieved.

The seeming simplicity of the technique of the Rammstedt operation is apt to appeal to every surgeon. However, as stated above, the Rammstedt operation is not as simple and safe a procedure as has been claimed by Rammstedt and others. In three out of eight cases of our series the duodenum was accidentally opened by three different surgeons. Such a repetition of the same serious accident is apt to create scepticism as to the

Fig. 8. Cross section through center of incision (Fig. 7, *d*).

Fig. 9. Cross section through proximal end of incision (Fig. 7, *e*).

merits of this operation. The number of our cases is too small to warrant any definite conclusion.

The operative mortality of 13 per cent among thirty-six gastro-enterostomized cases (combined statistics of Scudder, Stillman and Richter) compares favorably with Downes' mortality of 23 per cent, following the Rammstedt operation. It will require a much greater series of cases than heretofore published before it can be definitely decided whether the Rammstedt operation can really be considered as the method of choice or whether gastro-enterostomy, though less rapid

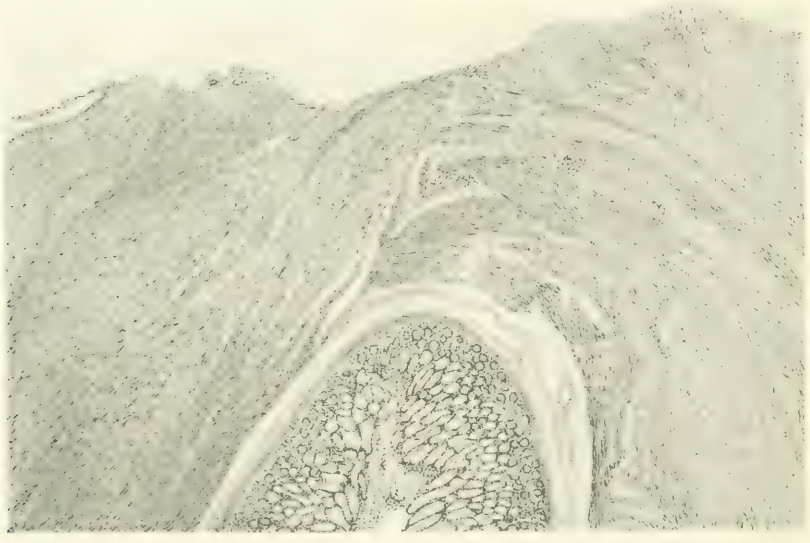

Fig. 10. Cross section through distal end of incision (Fig. 7, *f*).

in its execution, might not give better clinical results.

I wish to thank Dr. A. P. Stout for his kind help in the preparation of the histological reports.

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THE VALUE OF PYLORIC EXCLUSION IN THE TREATMENT OF PYLORIC AND DUODENAL ULCERS

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THE great value of gastro-enterostomy in the treatment of pyloric stenosis is an undisputed fact. If the obstruction is caused by a malignant growth, the operative result will, of course, be of temporary benefit only. If, on the other hand, the obstruction is caused by a benign ulcer of the pylorus or in the duodenum, gastro-enterostomy will effect a permanent cure. In fact, gastro-enterostomy in cases of benign pyloric obstructions gives undoubtedly the best clinical results. The benefit derived from this operation in cases of benign obstruction is much superior to the operative results following simple gastro-enterostomy in cases of non-obstructing ulcers of the pylorus or the duodenum.

The great efficiency of gastro-enterostomy in pyloric obstruction is based upon purely mechanical factors. The pylorus being completely obstructed, no food can pass into the intestines. Simple gastro-enterostomy reëstablishes the connection between stomach and intestines and restores an unobstructed way for the passage of food. Gastro-enterostomy thus acts as a simple drainage operation in cases of pyloric stenosis.

It is, however, a well-established fact that the great majority of pyloric and duodenal ulcers do not cause any physical obstruction. The clinical symptoms are not caused by a narrowing of the outlet of the stomach. The food can and does pass freely from the stomach into the small intestines. In fact, a great deal of the distress which the patients complain of is caused by the passage of food over the ulcer-bearing area.

Simple gastro-enterostomy could only be considered as the ideal operation for non-obstructing ulcers of the pylorus or duodenum, if the food could be permanently and absolutely sidetracked. Such result was formerly supposed to be attained. Gastro-enterostomy was first suggested for the treatment of non-obstructing ulcers of the pylorus and duodenum as a purely sidetracking procedure. Extensive experimental work on this question has, however, proved that this hypothesis is erroneous. Yet, even at the present day, many surgeons consider gastro-enterostomy as a safe procedure to keep food material away from the ulcer-bearing area.

As far back as 1900 Kelling made very extensive studies on the passage of the food following a gastro-enterostomy. He established two intestinal

fistulæ on gastro-enterostomized dogs, one in the jejunum, distal to the gastro-enterostomy, and one in the duodenum. He then injected 250 c.c. of water, colored with methylene blue, into the stomach and obtained 235 c.c. from the duodenal fistula and not more than 11 c.c. from the jejunal fistula. He concluded that occlusion of the pylorus offers the only guarantee for the patency of the gastro-enterostomy.

Röntgenoscopy and röntgenography offered a very good means for studying this question in animal experiments and on the human being. The literature on this subject has grown so rapidly during the last decade that it would be impossible to give a complete bibliography.

Hartmann pointed out that the stomach consists of two parts, the cardiac part, which acts as a reservoir, and the pyloric part, which acts as a motor. In other words, the food is mixed thoroughly with the gastric juice in the cardiac part of the stomach before it slides into the pyloric part. After its arrival in the pyloric part, the food is pushed promptly into the duodenum. He concludes from a series of animal experiments that if an anastomosis is made in the pyloric antrum, the evacuation of the food takes place principally through the stoma. If, however, an anastomosis is made in the fundus, the evacuation takes place principally through the pylorus.

Guibe's viewpoint is even more radical. "All the experiments on animals and observations on men seem to agree sufficiently to prove that as long as the pylorus remains permeable, the stomach has an almost invincible tendency to drive out its contents through this orifice without being inclined to utilize the artificial mouth. Nothing whatever passes through the new opening; on the contrary, everything passes through the pylorus."

Cannon, who studied this subject in a large series of animal experiments, came to the following conclusions: "The idea that gastro-enterostomy represents a drainage operation is wrong. There can be no doubt that in animal experiments the natural exit of the food is through the pylorus and not through the artificial opening, when both ways are offered for the passage of the food."

The same author in a thorough study, published some years previously with Blake, states that in the presence of a patent pylorus the food leaves through the pylorus rather than through the gastro-enterostomy stoma, no matter where the stoma is placed or how large the latter is made. Factors of peristalsis, pressure-relations and difference of food consistency in the cardiac and pyloric portions of the stomach make the pyloric passage a more natural exit than the artificial opening in other parts of the stomach.

Haertel observed, in a large series of radiographic observations, that the peristaltic wave of the stomach is unchanged after gastro-enterostomy. It is still directed toward the pylorus. He states that following gastro-enterostomy the food passes in equal parts through the pylorus and the stoma. Schueller's and Petrén's conclusions coincide with Haertel's views.

Outland, Skinner and Clendenning, on the other hand, came to entirely different conclusions. They claim that their röntgenographic experiments prove that gastro-enterostomy is a drainage operation and prevents the passage of food through the pylorus.

Thus, with the exception of Outland, Skinner and Clendenning, all authors above quoted agree that a considerable quantity of food passes through the pylorus, even in the presence of a patent stoma. Such a state of affairs is certainly not desirable. The healing of the ulcer will certainly be

hastened considerably if, at least for a certain length of time, the food can be completely and surely sidetracked. Different authors have suggested different forms of pyloric exclusion. In a former paper on this subject I have described the different methods of exclusion. I shall therefore refrain from discussing the relative value of these methods at length. The unilateral exclusion (Eiselsberg) and a modification of the Biondi method described in my previous paper on this subject are the only methods which guarantee a permanent exclusion. However, a temporary exclusion is sufficient to cure the ulcer. The exclusion stitch, introduced by Berg into clinical surgery, is the simplest and safest method of exclusion.

Berg's method is described by him in the following manner: "A double Pagenstecher linen suture, armed with a needle, is carried around the posterior stomach wall and is held in place by taking several bites in the anterior wall of the stomach. The suture is then tied and the pylorus thus occluded; the knot is buried by a few single stitches."

There is no doubt that röntgenography is a very good method to study the passage of the food following gastro-enterostomy. By this method, however, only short phases of the process are observed, as it is impracticable to watch the whole cycle from the time of intake of the food until complete emptying has occurred. Merely snapshot pictures are obtained, taken at different periods. At some future date this gap may be filled by röntgenographic motion pictures. Furthermore, some of these observations are rather doubtful as to their correct interpretation.

There is, however, a much simpler method which will demonstrate in permanent and preserved form the passage of the food through pylorus and stoma respectively. This method consists in the employment of stained fluids.

The choice of these fluids is a very limited one. In fact, among all the innumerable dyes, thionine blue represents the only one which answers our purpose. The mucosa of the stomach and intestines is covered with a rather thick layer of mucus. For this reason the dye to be employed must have a specific affinity for mucus. Methylene blue, for instance, will pass through the gastro-intestinal tract without coloring the wall, mixing only with the fæces. Another coloring medium which was tried first (*i.e.*, lamp-black) showed the same quality (intense colorization of the fæces without a trace of color on the mucous membranes).

Thionine blue, on the other hand, has a specific affinity for mucus. The first series of experiments was made with the German preparation which gave a dark blue color. The final experiments were made with an American product, as the foreign product was not obtainable on account of the war. This American product, though just as efficient, colored the specimens greenish instead of dark blue.

The experiments were performed in the following manner: Dogs were anæsthetized and a suture gastro-enterostomy or a suture gastro-enterostomy plus pyloric exclusion was performed. Two days after the operation 300

c.c. of a 2 per cent. thionine solution were injected into the stomach through a tube. The dogs were killed under chloroform anæsthesia on the following day.

The difference in the coloring of the duodenum in the excluded and non-excluded specimens is very obvious (see Figs. 1 and 2). In the first specimen (gastro-enterostomy and pyloric exclusion) the stomach mucosa and the jejunum distal to the stoma show a dark greenish color. The duodenum shows only a slight trace of color. In other words, the exclusion caused practically all of the thionine solution to be driven directly from the stomach into the jejunum without passing the pylorus. The slight trace of thionine solution in the duodenum is explained by the fact that the tobacco-pouch formation of the excluded pylorus allowed a few drops of fluid to pass through into the duodenum. Berg's exclusion is not complete for fluids. However, it prevents solid food absolutely from passing through the pylorus.

In the other specimen (gastro-enterostomy without pyloric exclusion), stomach, duodenum and jejunum show a dark green color of the same intensity. Evidently the solution has passed in about even proportions through the pylorus and the stoma.

This experiment thus demonstrated *ad oculos* the efficient way in which this simple method sidetracks the food.

It must be clearly understood that this series of experiments investigated the mechanical results which follow gastro-enterostomy. The changes produced in the chemistry of the stomach after gastro-enterostomy were not considered in these experiments. It is a well known fact that, following a gastro-enterostomy, bile and pancreatic juice are regurgitated through the stoma into the stomach, thus diminishing the hyperacidity considerably. This change of the chemism of the stomach is of the utmost importance. In fact, we believe that improvements in the clinical condition after gastro-enterostomy without pyloric exclusion are based solely upon the changes of the chemistry of the stomach. Gastro-enterostomy plus pyloric exclusion is however far superior to simple gastro-enterostomy. It gives the patient the benefit of the chemical changes just mentioned and, in addition to that, it safeguards the ulcers against mechanical insults, thus hastening the healing of the ulcer-bearing area.

I have shown in the paper above mentioned that pyloric exclusion does not exclude the pylorus permanently. However, the exclusion persists long enough to effect a rapid cure of the ulcer. It may be very advantageous that pyloric exclusion is of temporary nature only and that after the healing of the ulcer the normal passage of the food through the pylorus is partly restored. For it has been proved that hydrochloric acid will be neutralized much less efficiently if it passes from the stomach directly through the stoma into the intestines than if it takes its route *via* the duodenum. Diarrhœa, frequently encountered after gastro-enterostomy, is probably due to the action of the insufficiently neutralized hydrochloric acid on the intestinal mucosa.

FIG. 1.—Gastro-enterostomy with pyloric exclusion. (Surg. Path. 4355.)

FIG. 2.—Gastro-enterostomy without pyloric exclusion. (Surg. Path. 4340.)

The exclusion stitch does not add in any way to the risks of the operation. No accidents following its use have ever been recorded. Its proper application does not require more than a few seconds. It certainly improves the chances for a rapid disappearance of the distressing symptoms caused by pyloric and duodenal ulcers.

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A STUDY OF ANTE-OPERATIVE AND POST-OPERATIVE BLOOD COUNTS IN NON-INFECTIVE SURGICAL CONDITIONS

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THE blood count in acute infective surgical conditions has been of much interest and of great importance in diagnosis and prognosis for some time. Sondern [1] demonstrated its value beyond question by many observations and produced his "resistance line." His findings were very soon confirmed by many observers—Gibson,[2] Wilson,[3] Lampé,[4] and others.

The phenomenon of post-operative leucocytosis which occurs in those cases which have no acute infective process going on, although less frequently observed, should be of interest both to the surgical pathologist and to the operator who endeavors to minimize the injury of an operation.

A number of observers—Chadbourne,[5] Da Costa and Kalteyer,[6] Cabot, Blake and Hubbard [7]—found, some years ago, that there is a leucocytosis following operations under anæsthesia. Each group of men, however, has given a different explanation for the phenomenon. One attributes it chiefly to the anæsthetic; another, to the concentration of blood; a third, to the operation. None of them subjected the phenomenon to the ultimate analysis for obvious reasons—the causative factors may be so numerous that it is impossible to subject human beings, or even animals, to one factor at a time and observe the result of each. A study of any single case, for the same reasons, leads one into a maze of difficulties. It is only by taking a large

TABLE I

LIST OF OPERATIONS STUDIED

10 inguinal herniæ repair	1 amputation of toe
7 chronic appendicectomy	1 removal joint-mouse
5 dilatation and curettage	1 repair fracture of patella
3 hysteropexy	1 open reduction dislocation of shoulder
2 hysterectomy	1 colpoplasty
2 partial thyroidectomy	1 partial excision of omentum
2 partial phlebectomy for varicocele	1 ovarian cystectomy
2 Lane plating	1 closure fecal fistula
1 femoral hernia repair	1 laminectomy
1 excision lipoma of vulva	1 craniotomy
1 excision papilloma of breast	1 Percy cautery
1 epididymectomy	1 axillary dissection
1 amputation of leg	1 gastro-enterostomy

TABLE II

WHITE CELL COUNTS—51 CASES

Day of count		A. O.	P. O.	1	2	3	4	5	6	7	8	9	10	11	12
Case No.															
1	L. S.	9,300	20,650	18,750	14,550	10,100	12,100	9,100	.....	.....	.....	.....	.....	.....	.....
2	G. C.	9,150	20,200	16,550	11,700	11,100	8,350	8,750	8,550	.....	.....	.....	.....	.....	.....
3	J. B.	7,150	20,800	17,550	12,200	10,150	9,100	6,050	.....	.....	.....	.....	.....	.....	.....
4	*R. M.	13,400	26,600	16,550	12,800	10,350	9,700	11,550	13,200	11,350	9,100	.....	.....	.....	.....
5	†J. Q.	10,600	17,800	20,600	20,900	15,800	15,900	17,600	19,650	10,050	.....	14,500	11,900	.....	9,950
6	A. L.	11,450	20,050	20,050	12,400	14,000	11,350	9,550	9,500	.....	.....	.....	.....	.....	.....
7	M. L.	8,700	17,700	11,550	12,450	11,650	11,900	8,450	.....	.....	.....	.....	.....	.....	.....
8	†M. D.	8,100	9,900	7,100	7,450	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	W. H.	14,150	25,650	21,800	17,650	12,600	12,300	12,800	12,750	13,600	14,150	.....	12,000	.....	13,050
10	E. K.	14,350	21,750	35,700	14,200	11,100	9,200	7,400	.....	.....	.....	.....	.....	.....	.....
11	‡M. A.	19,400	28,950	27,450	29,600	20,000	21,900	19,750	18,550	15,400	.....	.....	.....	.....	.....
12	A. T.	11,150	21,350	15,000	16,800	8,300	8,800	.....	.....	.....	.....	.....	.....	.....	.....
13	H. S.	9,900	27,750	16,200	17,550	12,250	10,700	12,700	10,150	7,300	.....	.....	.....	.....	.....
14	†H. E.	8,800	29,050	14,800	15,050	9,050	9,650	10,400	15,800	11,100	14,000	13,000	.....	8,800	.....
15	E. D.	11,550	18,350	13,500	11,350	15,650	10,700	11,300	.....	.....	.....	.....	.....	.....	.....
16	H. S.	9,050	19,000	15,000	11,350	9,550	.....	.....	.....	.....	.....	.....	.....	.....	.....
17	A. F.	6,250	18,100	9,050	9,800	8,500	.....	.....	.....	.....	.....	.....	.....	.....	.....
18	*J. D.	12,550	15,050	13,350	10,000	8,250	8,400	.....	.....	.....	.....	.....	.....	.....	.....
19	*W. P.	13,950	23,200	19,800	16,250	9,950	7,150	.....	.....	.....	.....	.....	.....	.....	.....
20	†J. G.	9,300	15,700	16,500	15,350	15,200	16,000	11,700	11,650	16,350	.....	.....	.....	.....	.....
21	†H. O.	9,500	21,000	11,750	9,600	6,700	5,600	.....	.....	.....	.....	.....	.....	.....	.....
22	A. N.	6,000	20,800	17,400	13,500	11,000	12,050	10,100	9,600	9,300	9,100	7,250	.....	.....	.....
23	S. L.	8,250	17,100	11,000	11,350	9,050	11,400	10,400	14,250	9,400	.....	9,900	.....	.....	.....
24	A. S.	10,300	33,050	17,700	16,600	13,400	12,400	10,450	10,250	10,650	.....	10,650	.....	10,950	.....
25	M. K.	10,500	14,600	11,950	11,600	7,450	8,200	7,950	8,050	.....	.....	.....	.....	.....	.....
26	L. Z.	9,100	16,600	10,200	10,800	8,500	5,900	.....	.....	.....	.....	.....	.....	.....	.....
27	R. B.	9,250	30,000	16,950	14,700	9,900	11,000	11,800	8,600	8,300	.....	.....	.....	.....	.....
28	E. K.	12,150	13,100	12,250	11,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
29	H. S.	9,000	16,950	13,300	10,150	7,950	7,400	.....	.....	.....	.....	.....	.....	.....	.....
30	*N. N.	13,600	18,050	22,700	15,800	13,550	10,700	10,800	12,150	10,800	14,600	12,200	8,600	.....	.....
31	B. W.	6,450	14,200	9,850	7,300	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
32	G. S.	8,000	14,750	10,700	10,200	10,100	8,000	.....	.....	.....	.....	.....	.....	.....	.....
33	F. S.	7,100	14,000	8,900	9,200	8,050	.....	.....	.....	.....	.....	.....	.....	.....	.....
34	E. M.	8,150	20,600	12,850	12,500	11,600	8,300	8,750	.....	.....	.....	.....	.....	.....	.....

35	M. E.	13,050	32,750	20,400	15,950	13,250	10,150	11,700	14,050	10,700	11,650	12,750	.....	.....
36	†I. B.	6,300	17,300	.....	10,800	6,500	.....	.....	.....	.....	.....	.....	.....	.....
37	H. M.	11,250	17,500	12,550	6,700	.....	.....	.....	.....	.....	.....	.....	.....	.....
38	H. C.	12,200	37,100	21,150	16,050	17,300	13,600	16,700	15,500	10,000	10,400	11,850	10,900	.....
39	*C. N.	12,150	19,500	16,250	12,600	16,700	11,000	8,350	.....	.....	.....	.....	.....	.....
40	L. G.	11,900	15,100	13,900	12,200	17,700	13,350	10,650	.....	.....	.....	.....	.....	.....
41	*J. S.	13,100	32,600	19,000	20,100	16,400	12,000	.....	12,700	12,550	12,500	.....	.....	.....
42	J. R.	10,100	21,150	19,800	12,000	10,200	10,650	.....	12,950	8,500	.....	.....	.....	.....
43	M. K.	11,300	22,500	21,650	16,650	.....	9,800	8,200	.....	.....	.....	.....	.....	.....
44	†B. A.	8,800	17,300	13,000	.....	12,200	14,500	12,250	12,250	10,800	12,250	14,250	11,700	8,400
45	I. S.	10,550	24,950	20,000	14,400	13,000	11,000	8,900	7,400	.....	.....	.....	.....	.....
46	†A. S.	9,600	15,950	12,900	10,900	11,450	13,600	9,150	8,050	.....	.....	.....	.....	.....
47	H. N.	8,900	26,300	16,300	17,050	10,900	9,300	7,850	.....	.....	.....	.....	.....	.....
48	†B. Z.	9,600	19,050	16,650	12,500	11,600	.....	.....	.....	.....	.....	.....	.....	.....
49	J. B.	6,300	17,050	11,350	11,700	7,900	.....	.....	.....	.....	.....	.....	.....	.....
50	A. E.	10,250	27,400	17,450	16,400	11,800	9,650	10,000	10,200	11,400	10,900	.....	.....	.....
51	M. A.	10,250	25,250	17,650	15,700	12,450	12,300	10,350	10,550	.....	.....	.....	.....	.....

* Large hernia.
† Infected.
‡ Carcinoma of the uterus with degeneration.

number of cases which have some one thing in common, that this highest common factor, so to speak, can stand out prominently and the individual variations be reduced to a minimum.

Plan.—With the purpose of finding out the extent of post-operative leucocytosis in man and at the same time arriving, if possible, at some conclusions regarding the prime factors in its production, 51 cases were studied in the wards of the Presbyterian Hospital. These cases were chosen at random, the only cases not accepted in the series being those in which an acute infection was present before operation or a marked infection expected after it. A glance at Table I will reveal the diversity of the cases studied.

In planning the study, I tried to consider all of the factors which might have a bearing on the subject, in the periods before, during, and after operation. In each case the following data were obtained—the age, sex, and type of individual; the character, length and severity of the operation; the degree of trauma to the tissues and the number of foreign bodies introduced; the estimated blood and other body fluids lost by sweating and vomiting (in some cases also the fluid intake and urinary output); the method and kind of anæsthetic and the length of anæsthesia; and the general condition of the patient as indicated by appearance, respiration and pulse during the anæsthetic. In the post-operative course of the patient, notes were made on the condition of the wound found at dressings. Also the maximum and minimum temperatures for each day were charted as long as the blood counting was continued. Individual charts were made and curves plotted for the total white and red cell counts and the per cent. of polynuclears.

An ante-operative (A. O.) count was made on the afternoon before the morning operation (in a very few cases just before operation). A second count was made on the afternoon of the day of operation, approximately six hours post operation (P. O.). Another count was made every afternoon following until it returned either to normal or to the initial count. In making averages, those cases which fell to normal before the twelfth day were considered to maintain their final count until that day.

In all of the 51 cases a daily white cell count was made. In 39 a daily differential count was made. In 26 the red cells were counted A. O. and P. O., and on alternate days thereafter.

Although individual charts were made, I have not attempted to draw conclusions from any one case, but I have so grouped the cases according to the common factors, that certain very significant points are brought out.

Findings.—In every single case the white count rose six hours after operation—in 2 cases slightly, in 6 cases to an extreme degree, but in the large majority, quite uniformly doubling itself. Tables II, III and IV give the complete results.

The careful observation of the condition of the wounds at dressings revealed slight infection of the wound in 7 cases and moderate infection in 2 cases—positive cultures being obtained in 6 cases. These 9 cases have been set aside because of the frank presence of a generally accepted leucocyte stimulant. The other 42 cases have been studied both as a whole and divided

TABLE III

Red Cell Counts—26 Cases

Day of count	A. O.	P. O.	2	4	6	8	10	12
Case No.								
14	4,660,000	4,820,000	3,020,000	3,110,000	.....	.....	.....	.....
15	4,770,000	4,930,000	4,760,000	4,040,000	.....	.....	.....	.....
16	5,040,000	4,770,000	4,500,000	.....	.....	.....	.....	.....
17	4,990,000	5,730,000	5,310,000	.....	.....	.....	.....	.....
18	4,990,000	4,600,000	5,080,000	4,780,000	.....	.....	.....	.....
19	4,466,000	4,840,000	4,440,000	4,550,000	.....	.....	.....	.....
20	5,400,000	4,980,000	5,270,000	5,690,000	6,740,000	.....	.....	.....
21	6,300,000	5,290,000	6,050,000	6,440,000	.....	.....	.....	.....
22	5,480,000	6,260,000	4,860,000	4,980,000	4,130,000	4,100,000	.....	.....
23	5,310,000	5,560,000	5,330,000	4,740,000	4,680,000	4,100,000	.....	.....
24	.....	5,240,000	3,720,000	4,210,000	3,950,000	3,880,000	.....	.....
25	3,070,000	3,060,000	4,280,000	3,680,000	3,620,000	.....	.....	.....
26	5,340,000	4,620,000	5,170,000	5,060,000	.....	.....	.....	.....
27	5,190,000	5,990,000	5,270,000	5,110,000	4,140,000	.....	.....	.....
28	3,940,000	4,310,000	4,860,000	.....	.....	.....	.....	.....
29	5,860,000	5,480,000	5,080,000	4,450,000	.....	.....	.....	.....
*30	6,120,000	4,664,000	6,090,000	4,760,000	5,030,000	6,220,000	4,590,000	.....
31	4,070,000	4,850,000	3,650,000	.....	.....	.....	.....	.....
32	4,224,000	3,630,000	3,630,000	4,790,000	.....	.....	.....	.....
33	4,660,000	5,112,000	4,944,000	.....	.....	.....	.....	.....
34	5,240,000	5,470,000	5,380,000	5,760,000	.....	.....	.....	.....
35	5,448,000	4,344,000	4,740,000	4,424,000	4,950,000	4,330,000	4,224,000	.....
36	4,680,000	5,136,000	5,190,000					
37	4,290,000	4,170,000	4,640,000	.....	.....	.....	.....	.....
38	5,280,000	4,950,000	3,520,000	4,176,000	4,370,000	3,056,000	3,770,000	.....
39	5,940,000	6,300,000	5,670,000	4,976,000	.....	.....	.....	.....

* No explanation could be found for the wide variations in this case.

TABLE IV

POLYMORPHONUCLEAR PERCENTAGE—39 CASES

Day of count	A. O.	P. O.	1	2	3	4	5	6	7	8	9	10	11	12
Case No.														
1	67	91	78	75	70	69	....	....	....	....	....	....	....	....
2	36	79	63	63	60	63	55	51	....	....	....	....	....	....
3	70	93	76	81	84.5	76	72	....	....	....	....	....	....	....
4	62	88	69	79	67	67	65	78	66	55	....	....	....	....
5	55	90	83	84	81	83	80	86	85	....	76	86	....	77
6	58	91	86	68	59	....	61	51	....	....	....	....	....	....
7	50	88	70	76.5	69	64	55	....	....	....	....	....	....	....
8	72	84	71	70	....	....	....	....	....	....	....	....	....	....
9	65	86	79	75	76	71	66	59	65.5	72	....	65	....	60
10	70	84	80	69	75	62	56	....	....	....	....	....	....	....
11	85	93	92	86	84	82	87	83.5	80.5	....	....	....	....	....
12	72	89	77	75	69	62	....	....	....	....	....	....	....	....
13	50	88	73	76	63	58	83	54	55	....	....	....	....	....
14	70	85.5	80.5	79	76.5	74.5	76	86	81	79	86	....	73	....
15	67	85.5	78.5	73	72	76	68	....	....	....	....	....	....	....
16	47	90	74	52	45.5	....	....	....	....	....	....	....	....	....
17	67	85.5	67	79	70	....	....	....	....	....	....	....	....	....
18	73	89	70	72.5	66	67.5	....	....	....	....	....	....	....	....
19	85.5	91	90	83.5	76.5	69.5	....	....	....	....	....	....	....	....
20	71	85	80	82.5	85.5	83.5	70	73.5	79.5	....	....	....	....	....
21	66.5	88	70.5	70.5	62.5	58	....	....	....	....	....	....	....	....
22	61	94.5	86.5	83.5	60	75.5	72	65.5	67	76	62	....	....	....
23	72	89.5	70.5	65	76	59	70.5	75.5	63	....	57	....	....	....
24	78	92	83.5	76	78	75	68	69	71.5	....	60	....	48	....
25	68.5	91	76	87	79.5	78.5	86.5	....	....	....	....	....	....	....
26	64	83.5	82	72.5	75.5	64	....	....	....	....	....	....	....	....
27	62	95.5	83.5	82	74	75	78	69.5	64.5	....	....	....	....	....
28	59	59	60	46	....	....	....	....	....	....	....	....	....	....
29	57	88.5	77.5	73	66	63	....	....	....	....	....	....	....	....
30	79	82	80.5	77.5	76.5	69.5	61.5	69	62	67	61.5	56	....	....
31	69	93	74.5	67	....	....	....	....	....	....	....	....	....	....
32	56	86	75	72.5	67.5	74	....	....	....	....	....	....	....	....
33	64	88	73	63	65	....	....	....	....	....	....	....	....	....
34	47.5	90	84	80	60.5	57.5	61.5	....	....	....	....	....	....	....
35	62	94.5	79.5	72	74	65.5	71	71	63.5	63.5	64	65	....	....
36	59.5	85.5	79	70.5	71.5	....	....	....	....	....	....	....	....	....
37	70.5	79.5	66.5	60	....	....	....	....	....	....	....	....	....	....
38	69	92.5	81.5	83	80.5	75	77	71.5	76.5	66	79	68.5	....	....
39	67.5	89	79	81.5	73	67.5	69.5	....	....	....	....	....	....	....

into groups according to various classifications, in the attempt to bring out the factors in the leucocytosis.

These classifications consider (*a*) the sex and type of individual, (*b*) the kind and duration of the anæsthetic, (*c*) the character of the operation with respect to contamination, (*d*) the degree of trauma to the tissues, (*e*) the number of foreign bodies introduced, and (*f*) the blood loss. The factor of concentration of the blood, which Da Costa and Kalteyer emphasize, was considered, but was found to have in itself so many sub-factors, that it was impossible to make any satisfactory classification upon that basis. In it there had to be considered—daily fluid intake and output; ante-operative purging; sweating, temperature and humidity of the operating room, and general weather conditions affecting sweating; vomiting during and after

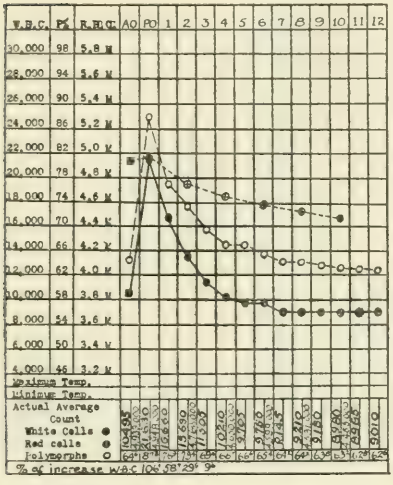

FIG. 1.—All of the 42 non-infected cases. White cell count in 42. Differential count in 33. Red cell count in 22.

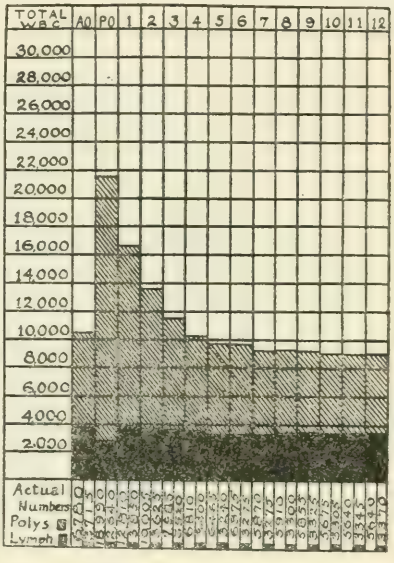

FIG. 2.—Showing that the leucocytosis is essentially a polynucleosis.

operation; post-operative colon irrigations, enemata and rectal administration of fluids. There were not two cases alike in all of these phases. Furthermore, the trivial rise in red cells (see Fig. 1) and the actual fall in lymphocytes (see Fig. 2) indicate that mere concentration of the blood is a minimal factor.

The composite curves in the 42 non-infected cases taken as a whole are shown in Fig. 1. The letters and numbers at the top indicate the days on which the counts were made. At the left are the figures representing the various levels of the count in white cells, red cells, and per cent. of polynuclears. At the bottom are the actual average figures and the per cent. of white cell increase over the initial count. The dots and solid lines represent the curve of the white cells, the circles and dash lines, the polynuclears, the wheels and dotted lines, the red cells.

In these cases it will be seen that the average A. O. blood count was as follows: White blood-cells, 10,495, polymorphonuclears, 64.6 per cent., red blood-cells, 4,939,000. Six hours P. O. it became: white blood-cells, 21,630, polymorphonuclears, 87.8 per cent., red blood-cells, 4,948,000. Thus, in six hours, the total white cells increased 106.1 per cent., the polymorphonuclears 36 per cent., and the red cells less than 0.2 per cent. On subsequent counts there was a rapid falling off of total white cells and polynuclears—the white cells falling below the initial count on the fourth day P. O. The polys fell more gradually but reached the initial count on the seventh day. The red cells fell gradually and progressively throughout the ten days P. O. with an average loss in that time of 451,000 cells per c.mm. An application of Sondern's [1] resistance line to this count would show a change in the direction of the line from a sharp decline to a slight rise on the first two counts with a subsequent return to the original direction.

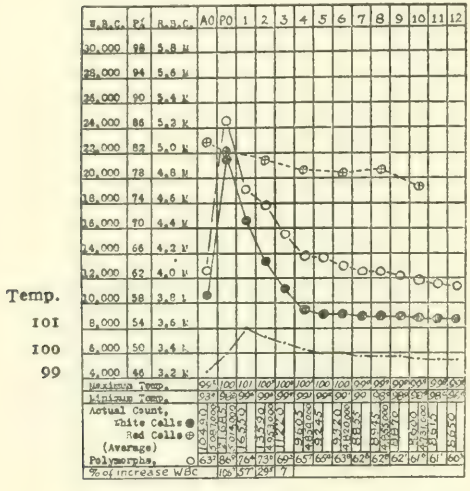

FIG. 3.—Clean cases. White cell count in 28. Differential count in 23. Red cell count in 14.

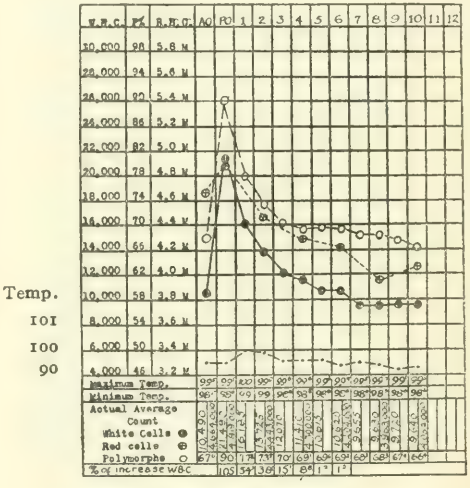

FIG. 4.—Borderline cases. White cell count in 14. Differential count in 10. Red cell count in 8.

Fig. 2 shows very plainly that the response is due entirely to the polymorphonuclear leucocytes, for the total number of these cells rapidly increases while the actual number of lymphocytes remains practically constant.

In order to determine the influence of infection and contamination, the 42 non-infected cases have been divided into clean cases, of which there were 28, and borderline cases, of which there were 14. Clean cases are considered to be those in which the operation from beginning to end is kept sterile, with no contamination of the operative field. Borderline cases are those in which a certain amount of contamination of the field is expected, such as occurs, for instance, in operations on the female genital tract or on the gastro-intestinal tract and its appendages (with the exception of the vermiform appendix operation which is clean). The composite curves for this division are shown in Figs. 3 and 4. With these curves, the reader

should compare Fig. 5 which gives the results in the 9 infected cases. On these three charts the composite temperature curves are also plotted. The uniformity with which the white count rises in these three groups is most striking. In the clean group the six-hour P. O. rise is 106.7 per cent. over the initial count. In the borderline cases it is 105 per cent. In the infected cases it is 105 per cent. This seems to indicate that infection or contamination has nothing whatever to do with the initial rise. The influence is seen, however, in the later days. In the clean cases the count returns to normal on the fourth day; in the borderline cases on the seventh day; in the infected cases not until the twelfth day. Infection, therefore, although it is not responsible for the rise, does delay the fall—the effect beginning on the second or third day P. O.

The temperature curves on these charts show that the rise in tempera-

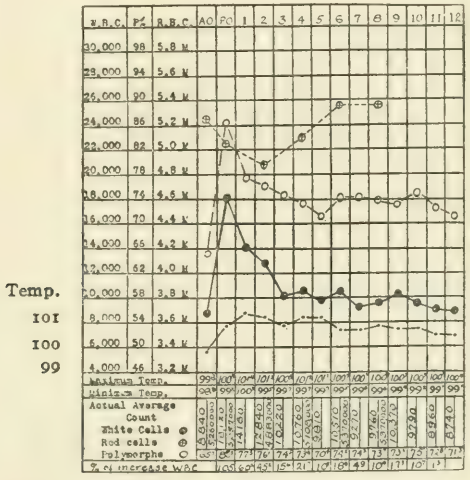

FIG. 5.—Infected cases. White cell count in 9. Differential count in 6. Red cell count in 4.

ture P. O. does not correspond, in time, to the rise in white cells, but is a later phenomenon of the post-operative reaction.

An interesting observation with respect to the infected cases is that in three of them Staphylococcus albus was recovered, and in all three the count fell to normal with the same rapidity that it did in the clean cases. With one exception, where other organisms were present, and in those cases in which positive cultures were not obtained (possibly anaërobic organisms were present) the count remained high.

Table V shows the cases grouped according to sex. Here it is seen that in 15 males the white cells increased 100.4 per cent. over the initial count, while in 27 females the rise was 108.7 per cent. Here there is a difference of only 8.3 per cent. The count in the male cases falls to normal one day before the count in the female cases. Apparently the factor of sex is unimportant.

TABLE V

CLASSIFICATION ACCORDING TO SEX

	Male, 15				Female, 27			
	White blood-cells	Per cent. of increase	Polymorpho-nuclears, per cent.	Red blood-cells	White blood-cells	Per cent. of increase	Polymorpho-nuclears, per cent.	Red blood-cells
A. O.	10,690	.....	64.1	5,241,000	10,380	.....	64.9	4,753,000
P. O.	21,475	100.4	86.9	4,983,000	21,600	108.7	88.4	4,932,000
1	16,135	50.9	75.6	.....	16,690	60.8	77.7	.....
2	13,865	27.8	75.8	5,059,000	13,640	31.4	72.1	4,604,000
3	11,265	5.4	70.9	.....	11,700	12.7	68.5	.....
4	9,220	.....	67.8	4,835,000	10,750	3.6	65.9	4,551,000
5	9,080	.....	67.2	.....	10,090	.....	64.9	.....
6	9,160	.....	66.5	4,865,000	10,090	.....	63.5	4,445,000
7	8,795	.....	65.7	.....	9,340	.....	63.5	.....
8	8,935	.....	66.3	5,016,000	9,370	.....	62.5	4,280,000
9	8,795	.....	65.9	.....	9,410	.....	62.1	.....
10	8,385	.....	65	4,812,000	9,300	.....	61.5	4,323,000
11	8,385	.....	65	.....	.....	.....	.....	.....
12	8,390	.....	64.6	.....	.....	.....	....	.....

TABLE VI

CLASSIFICATION ACCORDING TO TYPE OF INDIVIDUAL

	Average 20				Obese 14				Neurotic 5		Asthenic 3	
	White blood-cells	Per cent. of increase	Polymorphonuclears, per cent.	Red blood-cells	White blood-cells	Per cent. of increase	Polymorphonuclears, per cent.	Red blood-cells	White blood-cells	Per cent. of increase	White blood-cells	Per cent. of increase
A. O.	10,635	.....	63.9	5,043,000	10,500	.....	63.9	5,099,000	10,900	....	12,065	....
P. O.	22,725	113.7	90	5,235,000	21,505	104,8	86,2	4,708,000	18,380	68.7	20,200	67.4
1	16,165	52	77.7	.....	15,570	48.3	74.8	.....	19,620	80	16,915	40.2
2	13,615	28	73.6	4,735,000	13,200	25.7	73	4,855,000	12,580	15.4	17,635	46.2
3	11,640	9.4	69.7	.....	11,010	4.9	69	.....	12,200	12	11,750	....
4	10,300	.....	66.9	4,560,000	9,185	.....	65.5	4,826,000	10,250	....	12,665	5
5	9,575	.....	67.1	.....	9,345	.....	66.1	.....	9,980	....	11,865	....
6	9,360	.....	63.9	4,496,000	9,745	.....	67.5	4,889,000	10,130	....	11,500	....
7	9,090	.....	63.8	.....	8,865	.....	65.2	.....	9,180	....	10,450	....
8	9,160	.....	64.2	4,434,000	8,970	.....	63.7	4,801,000	9,140	....	.....	....
9	9,215	.....	63.5	.....	8,935	.....	63.8	.....	8,760	....	.....	....
10	9,025	.....	63.2	4,424,000	8,770	.....	62.4	4,686,000	8,760	....	.....	....
11	9,035	.....	62.5	.....	.....	.....	....	.....	.....	....	.....	....
12	9,090	.....	62.2	.....	.....	.....	....	.....	.....	....	.....	....

The classification according to the type of the individual divides the cases roughly into four groups: Average (20), obese (14), neurotic (5), and asthenic (3). These groups are shown in Table VI. We see by this group that the so-called average cases rise to 113.7 per cent. over the initial count. The obese cases rise to 104.8 per cent. The neurotic cases to 68.7 per cent. on the second count and 80 per cent. on the third. The three asthenic cases increased only 67.4 per cent. In the last two groups there are, of course, too few cases from which to draw definite conclusions, but apparently the factor of type of individual is important.

Figs. 6 and 7 show the curves in 24 ether cases and 18 gas and oxygen cases, respectively. The difference here is striking. In the ether cases the P. O. rise is 121.9 per cent. of the initial count with a return to normal on the fifth day. In the gas and oxygen cases the rise is only 85.1 per cent., and the return is on the fourth day. There is a difference here of 36.8

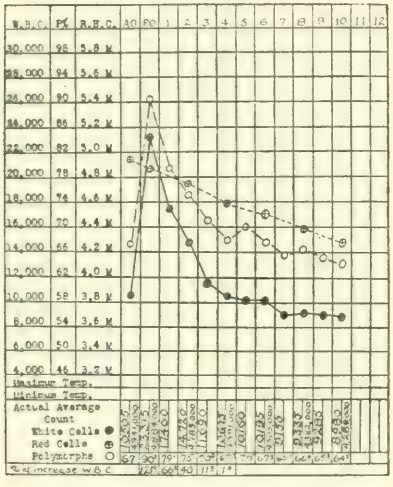

FIG. 6.—Ether cases. White cell count in 24. Differential count in 16. Red cell count in 11.

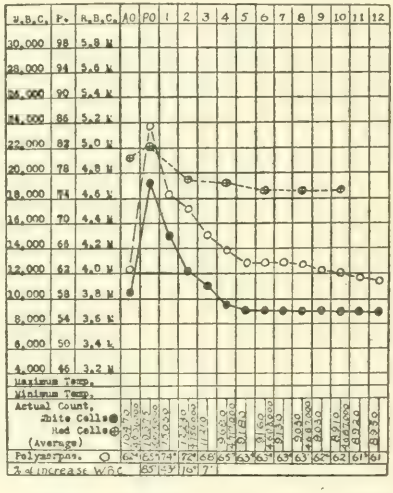

FIG 7.—Gas and oxygen cases. White cell count in 18. Differential count in 17. Red cell count in 11.

per cent. The red cell curves on these two charts show a much greater postoperative fall in the ether cases than in the gas and oxygen cases. In this series, there was no special selection of cases for either gas-oxygen, or ether. Long and short, severe and easy cases were performed under both ether and gas-oxygen. In most of the gas-oxygen cases a small amount of ether was used, from ʒj to ʒij.

The average duration of anæsthetic administration was found to be one hour and ten minutes. The cases were accordingly divided at this point into long-anæsthetic cases and short-anæsthetic cases. Table VII contrasts 19 long-anæsthetic cases where the increase is 114.4 per cent. and the return on the fourth day, with 23 short-anæsthetic cases where the count increased 97.9 per cent. and returned on the fourth day. The difference here is 16.5 per cent.—not striking but nevertheless real. It should be remembered that a much larger amount of anæsthetic is required

TABLE VII

CLASSIFICATION ACCORDING TO DURATION OF ANÆSTHESIA

	Short, 23				Long, 19			
	White blood-cells	Per cent. of increase	Polymorpho-nuclears, per cent.	Red blood-cells	White blood-cells	Per cent. of increase	Polymorpho-nuclears, per cent.	Red blood-cells
A. O.	9,885	....	61.7	4,782,000	11,225	.....	68.5	5,253,000
P. O.	19,565	97.9	81.5	4,871,000	24,080	114.5	89.2	5,077,000
1	14,610	47.8	74.8	.....	18.630	65.9	79.7	.....
2	12,085	22.3	71.4	4,796,000	15,495	38	76.7	4,720,000
3	10,865	9.9	67.7	.....	12,280	9.4	71.1	.....
4	9,535	....	64.5	4,657,000	11,025	.....	69.1	4,649,000
5	9,045	....	65.4	.....	10,505	.....	68.4	.....
6	9,000	....	64.8	4,579,000	10,665	.....	66.4	4,635,000
7	8,565	....	63.2	.....	9,840	.....	66.3	.....
8	8,465	....	62.6	4,538,000	10,105	.....	66.9	4,528,000
9	8,490	....	62.3	.....	10,015	.....	65.7	.....
10	8,490	....	62.3	4,538,000	9,570	.....	64.2	4,401,000
11	.....	....	....	.....	9,590	.....	63.3	.....
12	.....	....	....	.....	9,640	.....	63	.....

for the induction than for the last stages of anæsthesia, and perhaps the amount is a much more important factor than the mere duration, but this is difficult to measure, especially in the gas and oxygen cases. The difference in the red cell curves is more striking than the changes in the white cells—the red count falling much more rapidly in the cases with long anæsthesia.

The results in the classification according to the degree of trauma to the tissues are shown in Figs. 8 and 9. Trauma was considered to consist of cutting, tearing, and handling the tissues. Twenty-five cases were subjected to marked trauma and in these the rise was 114 per cent. over the initial count. Seventeen cases had only slight trauma and the rise was only 90.7 per cent. The difference between these is 23.7 per cent. In both, the

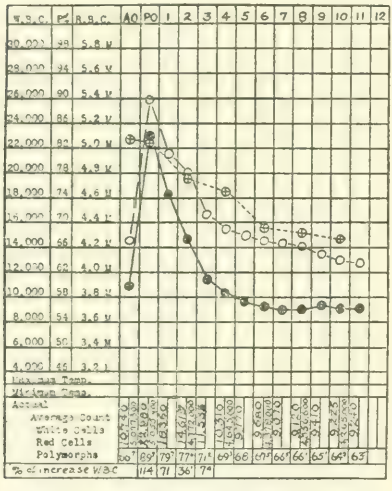

FIG. 8.—Cases receiving marked trauma. White cell count in 25. Differential count in 19. Red cell count in 10.

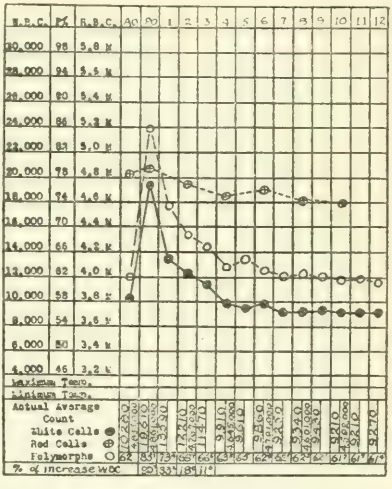

FIG. 9.—Cases undergoing slight trauma. White cell count in 17. Differential count in 15. Red cell count in 12.

count returned to normal on the fourth day. Here also the progressive anæmia is more pronounced in the cases with increased trauma than in those with slight trauma.

The cases were also divided into two groups according to the number of foreign bodies left in the tissues. At the time of operation every stitch and ligature was counted. In this summary no differentiation is made between the various materials used. Each stitch and ligature was counted as 1 and in the four cases in which drainage for bleeding was necessary, each drain was counted arbitrarily as 5. The average was 40. Fig. 10 shows 19 cases which had more than 40 foreign bodies left in. The rise here is 119 per cent. over the initial count. Fig. 11 shows the composite curves in 23 cases in which less than 40 foreign bodies were introduced. The rise in these cases is 96.3 per cent., and the difference between the two groups is 22.7 per cent. The stimulating effect of suture material, however, does not seem to be of long duration, since those cases with many foreign bodies

return to normal before those with few. The fall in red cells is practically the same in these two groups.

The last grouping is according to the blood loss. In only one case was there any large amount of blood lost (9 ounces). The smallest amount was 1 drachm. The average was found to be 2 ounces. The 22 cases in which more than that amount was lost are shown in Fig. 12. Here the initial rise is seen to be 119.7 per cent., falling on the fifth day. In 20 cases losing less than 2 ounces (Fig. 13) the rise is 90.3 per cent., falling on the fourth day. The difference is 29.4 per cent.

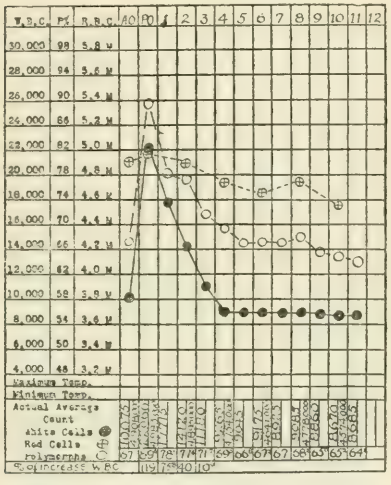

FIG. 10.—Cases retaining more than forty foreign bodies. White cell count in 19. Differential count in 12. Red cell count in 8.

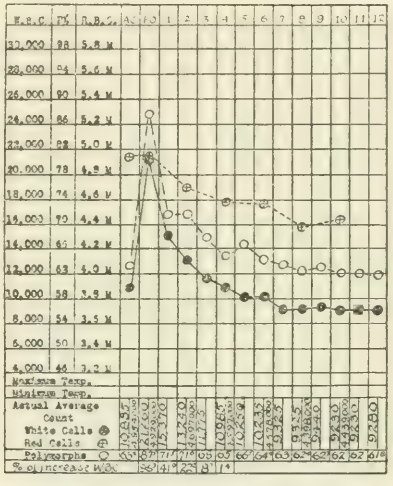

FIG. 11.—Cases retaining less than forty foreign bodies. White cell count in 23. Differential count in 21. Red cell count in 14.

DISCUSSION

From the first five charts certain facts are available. From the others only inferences may be drawn. It is a fairly generally accepted theory that the outpouring of leucocytes is a reaction to injury. If that theory be true, there are two variable factors—first, the kind or degree of injury; second, the resistance or vigor of the reacting individual. Up to a certain point the greater the injury and the greater the resistance of the individual, the greater will be the reaction. The foregoing charts indicate that an operation performed under an anæsthetic is sufficient injury to cause a marked increase in the white cell count. Severe trauma to the tissues and organs, introduction of a large number of foreign bodies, long anæsthesias, especially with ether, and much loss of blood, cause the greatest reactions and may be considered to be the severest injuries. All of these factors are more or less under the control of the operating surgeon. The resistance of the patient is not so easily controlled, but it must be considered as an active factor in the variation in the count. If the above observations be true, it is obvious that any case having all of the above leucocyte stimulating factors ought to have a very high count. On the other hand, any case

having none of these factors ought to have a very low count. There are just three cases in this series which represent these extremes and their charts bear out the points just made. The curves of two of these are shown in Figs. 14 and 15. The first case is an average female with long ether anæsthesia, increased trauma, many stitches, and much loss of blood. The second case is an obese male with a short gas and oxygen anæsthesia, slight trauma, few stitches, and small loss of blood.

The third case, in which only the white cells were counted, shows this even more strikingly—L. A., an average female—ether anæsthesia for one

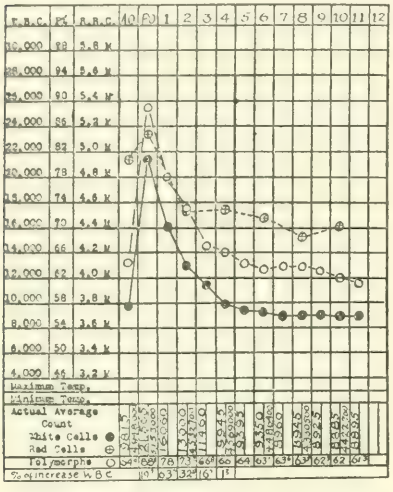

FIG. 12.—Cases losing more than two ounces of blood. White cell count in 22. Differential count in 15. Red cell count in 11.

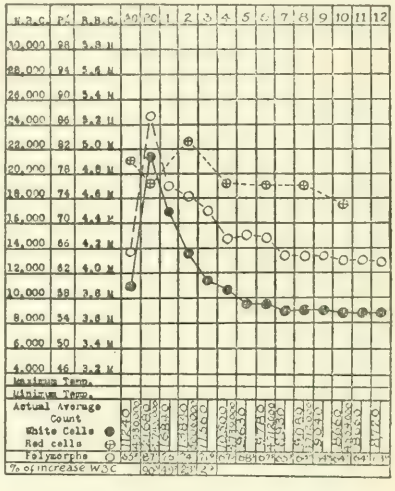

FIG. 13.—Cases losing less than two ounces of blood. White cell count in 20. Differential count in 18. Red cell count in 11.

hour and twenty-eight minutes, marked trauma, 62 foreign bodies introduced, blood loss, 4 ounces. The count follows:

	White blood-cells	Per cent. of increase
A.O.	10,250	.....
P.O.	25,250	146.3
1	17,650	72.2
2	15,700	53.1
3	12,450	21.5
4	12,300	20
5	10,350	1
6	10,550	1

The absolute control of every factor mentioned above is impossible either with human beings or with experimental animals. Some attempt has been made to control certain of them, however.

1. The variation between the sexes with respect to the blood reaction to injury has never been carefully observed. The slight difference in the reaction given by the two sexes in this series may be accidental, or it may be due

to the fact that the average female ward patient is generally in relatively better physical condition than the average male ward patient.

2. It has frequently been found in acute infective conditions that a weak individual gives a weak leucocytic response to the infection. Likewise, in non-infective conditions, apparently, the "average" patient, who is obviously more healthy than the obese, the neurotic, or the asthenic, is more capable of giving a strong reaction. An interesting observation was made in one of my cases—a very neurotic individual. The evening before the day scheduled for operation, she became almost panic stricken with fear and in the morning refused operation. The count went up from 12,200 to 17,400 without operation. This was considered at the time to be a neurotic manifestation, but Table V seems to show that nervousness is not a leucocytic

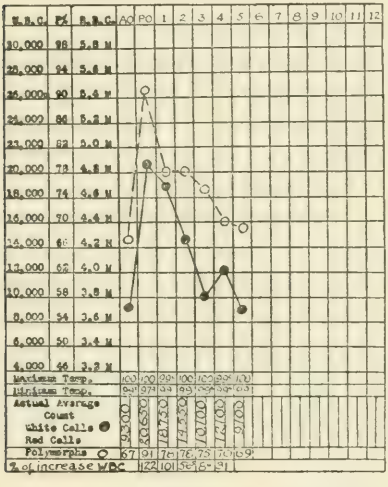

FIG. 14.—Case showing all of the leucocyte stimulating factors. Average female; ether, one hour twenty minutes; marked trauma; foreign bodies, forty-eight; blood loss, three ounces.

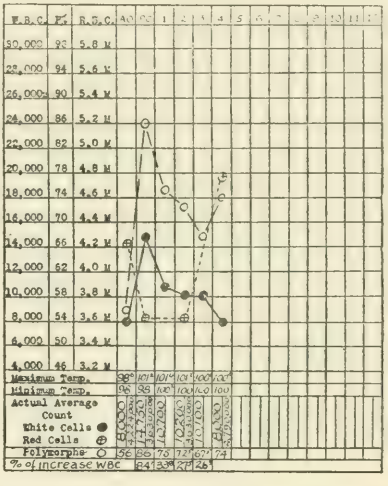

FIG. 15.—Case showing a minimum number of leucocyte stimulating factors. Obese male; gas and oxygen, one hour nine minutes; slight trauma; foreign bodies, twenty-nine; blood loss, three drachms.

stimulant. One of the other neurotic cases was one of the two cases to have only a slight post-operative rise (Case 28).

3. Mann [8] has shown that where anæsthesia in dogs is kept up continuously for three or four hours, there is a doubling of the count at the end of four hours. Krumbaar [9] likewise showed that anæsthesia in dogs causes a leucocytosis. Chadbourne [5] found this increase to be most marked in the early stages of anæsthesia. I counted one case in the hospital which seems to bear out this observation. Unfortunately, no ante-operative count was made. The first count was made three minutes after anæsthesia had started. Thereafter a count was made every fifteen minutes throughout a two-hour operation. The case was a very difficult double hernia with balls of omentum down in the scrotum. (Incidentally I may say that large herniæ frequently give counts between 10,000 and 15,000 A. O.) This count follows:

3 minutes, white blood cells	18,450	Polymorphonuclears, 74	per cent.
18 minutes, white blood cells	23,500	Polymorphonuclears, 64	per cent.
33 minutes, white blood cells	27,950	Polymorphonuclears, 61	per cent.
48 minutes, white blood cells	27,750	Polymorphonuclears, 62	per cent.
63 minutes, white blood cells	29,450	Polymorphonuclears, 69½	per cent.
78 minutes, white blood cells	26,750	Polymorphonuclears, 68	per cent.
93 minutes, white blood cells	29,450	Polymorphonuclears, 62½	per cent.
108 minutes, white blood cells	29,750	Polymorphonuclears, ...	per cent.
After 6 hours, white blood cells	32,800	Polymorphonuclears, 90½	per cent.
First day P.O., white blood cells	22,350	Polymorphonuclears, 86½	per cent.
Second day P.O., white blood cells	16,550	Polymorphonuclears, 84½	per cent.
Third day P.O., white blood cells	13,550	Polymorphonuclears, 72	per cent.
Fourth day P.O., white blood cells	9,700	Polymorphonuclears, 73	per cent.
Fifth day P.O., white blood cells	9,700	Polymorphonuclears, 69	per cent.

I have no explanation to offer for the fact that in this case the polymorphonuclears made a later rise than the total white cells.

Cabot, Blake and Hubbard [7] studied the effect of both anæsthetic and operation by counting the blood just before anæsthesia, again just before the operation, and a third time just after the operation. They found practically no rise in the second count, but in half of the cases the count immediately after operation was increased. Thus their study of the effect of the anæsthetic covered only ten to twenty minutes time, and no account was taken of the possible late effect of either anæsthetic or operation. It would be difficult in human beings to obtain a large series of cases in which an anæsthetic was given without some kind of an operation following it. I counted one case in which a closed reduction of the shoulder was attempted under ether. Here there was some trauma to the tissues but no introduction of foreign bodies and no loss of blood. The anæsthetic lasted twenty minutes. The leucocytes ran as follows:

Just before anæsthesia, white blood cells	6,300
Just after operation, white blood cells	6,300
Six hours P.O., white blood cells	13,200
First day P.O., white blood cells	11,800
Second day P.O., white blood cells	8,300
Third day P.O., white blood cells	10,400
Fourth day P.O., white blood cells	8,300

It is somewhat easier to control the factor of anæsthesia by exclusion, *i.e.*, by counting a series of cases performed under local anæsthesia. This I did in four cases with the following results:

1. A.O., white blood cells	7,600	Polymorphonuclears, 40	per cent.
P.O. (8 hrs.), white blood cells	14,450	Polymorphonuclears, 79	per cent.
2. A.O., white blood cells	8,400	Polymorphonuclears, 63	per cent.
P.O. (8 hrs.), white blood cells	14,800	Polymorphonuclears, 73	per cent.
3. A.O., white blood cells	8,000	Polymorphonuclears, 54	per cent.
P.O. (14 hrs.), white blood cells	12,350	Polymorphonuclears, 74	per cent.
4. A.O., white blood cells	9,700	Polymorphonuclears, 61	per cent.
P.O. (6 hrs.), white blood cells	12,000	Polymorphonuclears, 81	per cent.

Cases 1 and 2 were herniæ. Cases 3 and 4 were varicoceles. Of course, these cases are relatively simple and are in no sense representative operations with respect to trauma, foreign body introduction or blood loss, nevertheless, the counts show that the operation itself is a definite leucocytic stimulant, even if it is not the only one.

4. The factors of trauma and foreign body introduction cannot be controlled in human beings separately, and ordinarily they are complicated by the factors of anæsthesia and blood loss. Furthermore it is not practical to attempt to show the importance of one or another form of suture material used in operations on human beings, since, in practically every case, all forms are introduced. Lampé [4] showed in a few cases in dogs that iodized catgut produced a higher leucocytosis than silk, when used in operations.

5. The factor of blood loss has been studied by Krumbaar,[9] who has recently shown that the removal of 75 to 100 c.c. of blood produces a leucocytosis in dogs, even when no anæsthetic has been given. If this be true in human beings, for relatively small amounts, as Figs. 12 and 13 seem to indicate, the loss of large amounts of blood does not seem to have a corresponding effect. I made counts on three donors for transfusion. Five hundred c.c. of blood was taken from each one without anæsthetic. Although no definite conclusions can be drawn from only three cases, I introduce their counts here, considering them to be interesting observations in this connection.

	First case	Second case	Third case
Just before phlebotomy, white blood cells	6,200	8,200	10,800
Just after phlebotomy, white blood cells	8,900	7,500	9,000
About 6 hours after phlebotomy, white blood cells	7,900	6,400	7,700
About 30 hours after phlebotomy, white blood cells	.....	.....	8,600

It is conceivable that where small losses of blood, up to a certain point, would stimulate leucocytosis, large amounts are too great to be more than just compensated for by the hæmatopoietic activity of the body.

CONCLUSIONS

1. In surgical cases undergoing operation without infection, the white cells increase in number, and about six hours after operation have more than doubled.

2. The response is due almost entirely to the outpouring of polymorphonuclear cells.

3. There is a trivial rise in red cells after operation, but in the subsequent ten days this is followed by a progressive anæmia with an average loss of about one-half million cells per c.mm.

4. The white cell count may be expected to fall rapidly in clean cases and reach normal on the fourth day. In infected or contaminated cases it will fall much more slowly.

5. Infection and contamination have nothing to do with the initial rise, but on the second or third day after operation they will tend to keep the count high.

6. Other things being equal, the count will be higher in those cases in which there are severe trauma to the tissues, many sutures and ligatures used, considerable loss of blood and long anæsthesia, especially with ether.

7. Normal individuals will produce a higher leucocytosis than abnormal types.

I wish to express my sincere thanks to Dr. Guy A. Caldwell for helping me plan this study and for counting foreign bodies introduced at operation.

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THE ROENTGENOGRAPHIC DEMONSTRATION OF THE SUBDURAL SPACE

ITS SIGNIFICANCE IN THE DIAGNOSIS OF INTRASPINAL LESIONS *

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Despite accurate diagnostic methods and careful study, tumors and other lesions of the spinal canal are by no means always found, at operation, at the level to which the physical examination points. There is, besides, a definite group of cases in which the diagnosis of intraspinal tumor is considered probable and in which the operative findings are negative or indicate the existence of spinal sclerosis. Finally, the presence of multiple tumors, situated at different levels of the spinal cord, cannot be established with any certainty before operation. In other words, the most painstaking neurologic examination, as at present constituted, falls short not infrequently in the determination of the presence of a spinal tumor and of its level, and in the diagnosis of multiple tumors at different levels.

As a result there are performed not a few unnecessary operations, or operations at incorrect levels. A method, therefore, was sought to aid in the accurate localization of all extradural, intradural or expanding intramedullary lesions— that is, of all lesions that encroach on the space occupied by the cerebrospinal fluid.

The method, as worked out in animal experimentation (dogs), consists in lumbar puncture done under full ether anesthesia, th evacuation of from 2 to 3 c.c. of cerebrospinal fluid, and its replacement by an equal amount of 10 per cent. collargol solution introduced by gravity. Anteroposterior and lateral roentgenograms of the spine are then taken. The roentgenograms are

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striking and uniform in the delineation of the subdural space. Except in the cervical region, the lateral are much clearer than the anteroposterior pictures. The roentgenogram is that of a sharply outlined strip on each side of the spinal cord. These strips or columns

Fig. 1.—Outline of the dorsolumbar part of the subdural space by collargol.

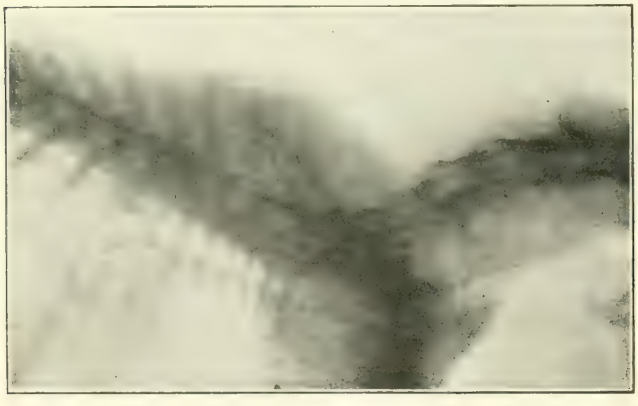

Fig. 2.—Outline of the cervicodorsal part of the subdural space.

represent, of course, the cylinder of collargol-impregnated cerebrospinal fluid surrounding the cord; the roentgenogram, having been taken "on the flat," brings out in relief the strip of fluid on each side of the cord. Stereoscopic pictures would give a more rounded effect.

It will be noted (Figs. 1, 2 and 3) that the shadows outlining the subdural space are remarkably smooth and uniform in the normal animal, presenting only slight variation in diameter at different levels of the cord. They are entirely free from any sharp indentations. If a foreign body (in imitation of a tumor or any other compressing lesion) is inserted either extradurally or intradurally, the collargol outline of the

Fig. 3. Outline of the lumbar subdural space, anteroposterior view.

canal either stops abruptly or is sharply indented, depending on the size of the foreign body. For examples, Figures 4 and 5 were taken one week after laminectomy in the lower dorsal region and extradural implantation of a thin sliver of laminaria. The dog was reanesthetized and collargol instilled. As corroborated by subsequent dissection, the parallel columns of collargol begin to converge a short distance below the moderately swollen foreign body, and come to a point a few millimeters above its upper end.

Although not quite germane to the subject, a few observations of interest which appeared in the course of this work will be briefly noted: 1. Judging by the roentgenograms, the space occupied by cerebrospinal

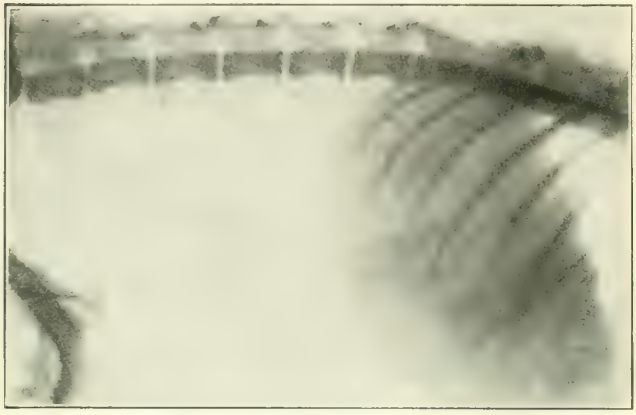

Fig. 4.—Laminectomy in lower dorsal region and extradural insertion of foreign body (laminaria), before collargol injection.

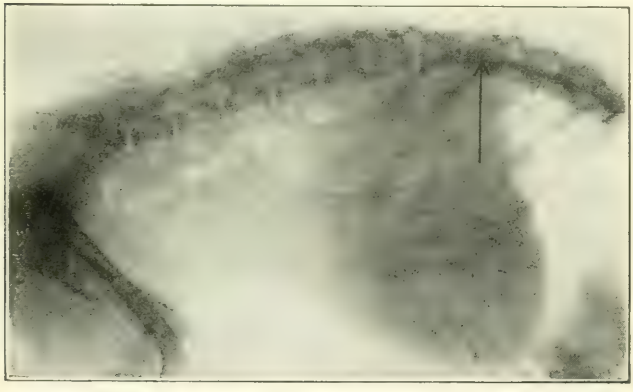

Fig. 5.—Collargol roentgenogram one week after extradural insertion of laminaria, revealing gradual narrowing of the subdural space and termination at the point indicated by the arrow; the outline of the cauda is indistinctly seen.

fluid posterior to the cord is normally wider than the anterior. If this exists in the human being it suggests an explanation for the fact that most spinal tumors are found dorsal to the cord. 2. Collargol roentgeno-

grams outline clearly not only the spinal cord proper but also the cauda equina. 3. The collargol solution was introduced by gravity with the dogs in the prone posture, and therefore was free to enter the cerebral subdural space in the absence of any artificial obstruc-

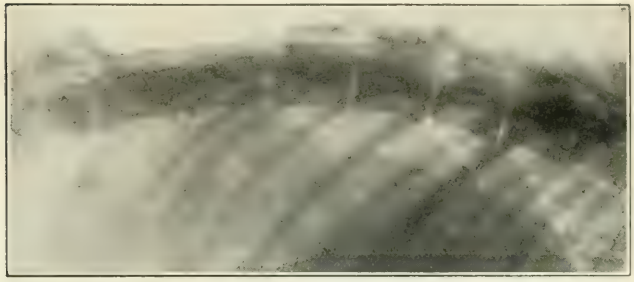

Fig. 6.—Lateral view of the effect of laminectomy and incision and suture of the dura, illustrating the use of the method for graphic study.

tion. As a result, striking outlines of the cerebral and cerebellar convolutions were obtained (Figs. 8 and 9). 4. It is remarkable to note how small a quantity of collargol solution—as little as 2 c.c.—is required to outline the entire cerebrospinal space.

Fig. 7.—Anteroposterior view of the effect of laminectomy and incision and suture of the dura.

The introduction of collargol into the subdural space of dogs was followed by shock and convulsions in several instances. Twice it appeared to be fatal; that is, the animals never recovered from ether anesthesia. It is true that, in human beings, the flow of collargol into the cerebral subdural space would be prevented by placing the patient in the sitting or reclining

posture, and by holding the funnel containing the solution no higher than the second or third cervical spine. Nevertheless (and despite the fact that the reports of its use in the treatment of meningitis do not suggest that it is dangerous) the intraspinal injection of collargol in human beings might be followed (as in the reported experiments) by serious manifestations and, therefore, cannot be advocated as a diagnostic procedure. In considering the application of the method to the human being it is certainly most desirable to employ a radioactive solution that gives greater likelihood of freedom from toxic or irritating

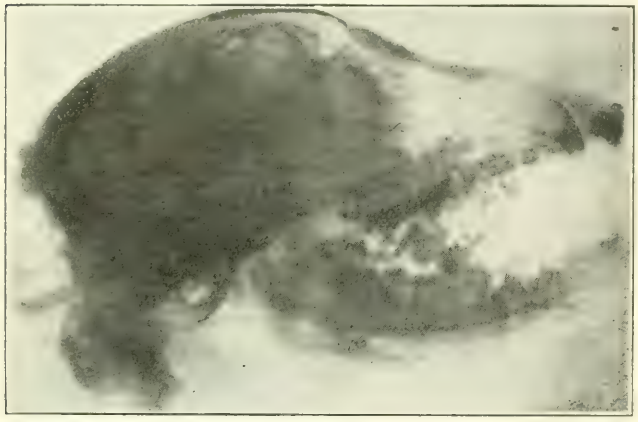

Fig. 8.—Outline of cerebral and cerebellar convolutions, lateral view.

effects. Thorium offers itself as such a solution. In the hands of Burns, who first described it is a substitute for collargol for roentgenography of the urinary tract, and of others, thorium has proved free from irritating or toxic symptoms. The roentgenograms are as clear and as sharp as those following the introduction of collargol. The questions of strength of solution, amounts, the probability or improbability of well defined pictures in the thicker spinal canal of the human being, etc., will be the subject of further investigation.

It may be added that it is my belief that in the intraspinal injection of relatively nonirritating or nontoxic solutions or suspensions of metals such as thorium may

be found a method of treatment of various intraspinal lesions not amenable to surgical therapy. If this should prove to be the case there would be a great added advantage in the Roentgen demonstration and consequent control of definite local applications of the substance to the site of the lesions. In any event, it is conceivable that the solution of the drug to be introduced into the spinal canal for therapeutic purposes could be admixed with the thorium solution to determine if, and how, the drug in question reaches intraspinal lesions.

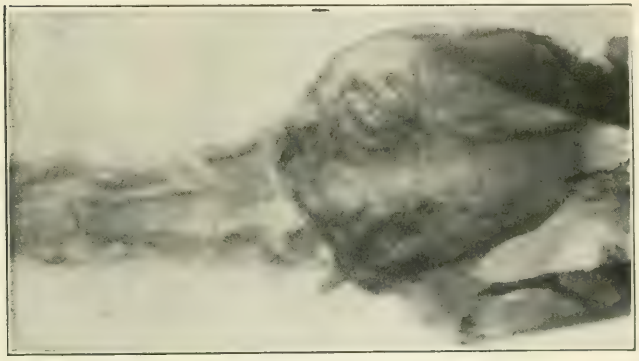

Fig. 9.—Outline of cerebral and cerebellar convolutions, viewed from above; the subdural space is seen; the definition of the convolutions is more clearly seen in the negatives.

The roentgenographic demonstration of the subdural space offers the following possibilities:

1. Experimentally: (*a*) a graphic study of the entire subdural space and of the surface morphology of the brain and spinal cord; and (*b*) a graphic demonstration of the effect of various experimental procedures on the configuration of the brain or spinal cord.

2. In the human being: (*a*) the demonstration of the exact situation of any intradural or extradural lesion encroaching on the spinal cord, or of any expanding intramedullary lesion; (*b*) the demonstration of multiple intraspinal lesions; (*c*) the demonstration of the absence of any encroachment on the cord; (*d*) a study of the effects of various operative procedures on the spinal cord or canal; (*e*) demonstration of local thera-

peutic application of drugs to intraspinal lesions, and (*f*) a graphic study of the normal and abnormal surface anatomy of the brain and spinal cord in the cadaver.

I am greatly indebted to Dr. Edgar Oppenheimer of New York for his cooperation in the Roentgen studies.

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NEUROTIZATION OF PARALYZED MUSCLES BY IMPLANTATION OF MOTOR NERVES.

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In 1906 Gersuny[1] noticed that incidental to the removal of a tumor of the face, a muscle which had been severed from its connection with the facial supply on that side, if replaced so that it lay in contact with the normally innervated muscles (from the facial) of the same or opposite side of the face, would ultimately regain its function. The case on which he based this theory was one of facial paralysis in which he dissected the orbicularis oris free and brought the sound portion of it past the midline, suturing it in this position. There was an ultimate return of function in the muscle.

Another case of his was a paralysis of the deltoid of unknown origin. Here he freed the deltoid and trapezius from their attachments to the acromion and scapular spine, and then brought up the paralyzed deltoid under the healthy trapezius and sutured it there. The arm was fixed horizontally. In 50 days the deltoid began to show return of function.

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Stimulation of the spinal accessory caused contraction of the trapezius, but stimulation of the circum-

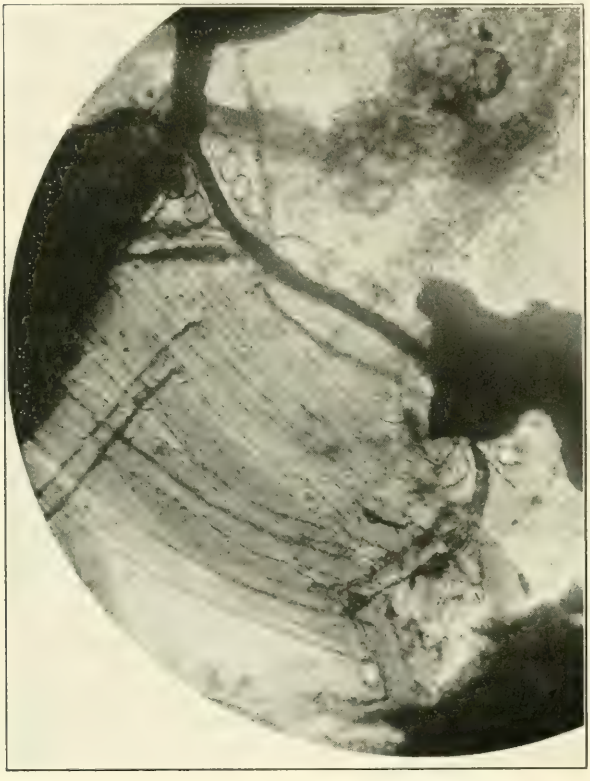

FIG. 1.

flex evoked no contraction of the deltoid. Frankl-Hochwart at the time pointed out that this was no

proof of non-function of the nerve—it is well known that voluntary contraction often returns before response to electrical stimulation.

In 1908 von Hacker divided the spinal accessory incidentally to extirpation of tuberculous cervical lymph nodes. There was a paralysis of the trapezius. Some time later (he does not state exactly) he implanted the central end of the cut nerve into the trapezius higher up, the peripheral end was implanted into the brachial plexus lower down, and, lastly, a flap from the levator scapulæ was implanted in the center of the trapezius. Apparently recovery was slow, for, at a second operation, the deltoid was freed and implanted into a freshened cross section of the trapezius. Two years later there was complete restoration of function.

In a second case, von Hacker performed neurolysis for a deltoid paralysis of three months' standing. There was no result six weeks later; he then freed a flap of healthy trapezius and brought it into contact with the deltoid fibers. Six weeks later there was a return of function—the anterior fibers of the deltoid reacted to electrical stimulation. None of the cases just described are conclusive.

In 1914 Heinecke[2] of Leipzig reported having cut the posterior tibial nerve in rabbits and then having implanted the peroneal into the paralyzed gastrocnemius. In 14 days function began to return and in 8 weeks there was complete restoration. Implantation as late as 21 days after paralysis was successful.

Shortly after, Erlacher[3] of Graz reported having been at work on this problem since 1911. In a monkey the musculocutaneous had been severed and then reimplanted at another point into the biceps. There was return of function. Many other experi-

FIG. 2.

ments (34 in all) were made on guinea pigs, using the biceps. As a result of these he claimed it was

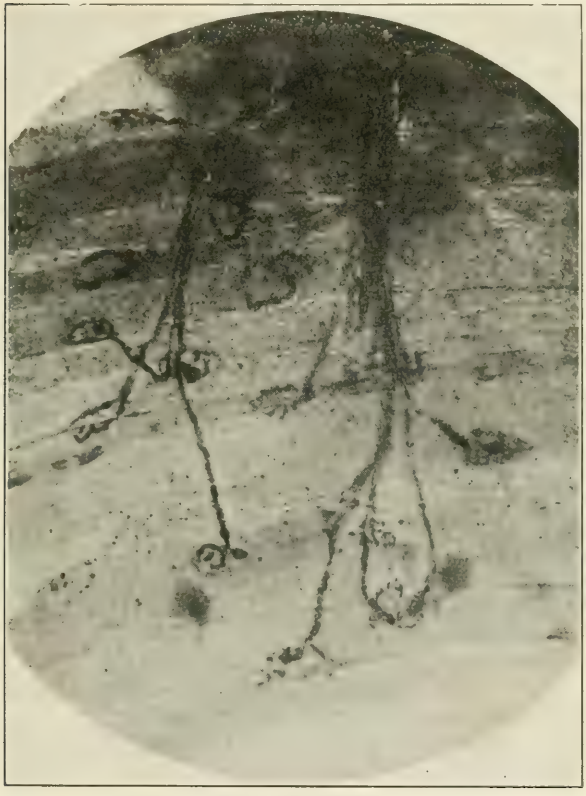

FIG. 3.

also possible to innervate (hyperneurotize) normal muscle with additional nerve trunks (by implanta-

tion), and lastly, to innervate paralyzed muscles by bringing their fibers intimately in contact with non-paralyzed muscular tissue.

Steindler[4] of Iowa City, in 1915, reported positive findings in 5 dogs. The anterior crural was resected and the sciatic was cut across low down, it was then implanted into the paralyzed quadriceps. After 10 weeks there was some return of function and after 16 weeks restoration was complete. He also reported innervation of paralyzed muscle in 3 cases of residual deformity following poliomyelitis (pes calcaneus with fair or good function of the long flexors of the toes). The posterior tibial was isolated and split; part of it was then implanted into the gastrocnemius by suture. There was return of function within 4 to 6 weeks.

In a later communication (1916) Steindler[5] recounted a second experimental series of 5 dogs and 2 cats in which the artificially paralyzed quadriceps was innervated by implantation of the cut anterior tibial.

In a recent number of *Science*, Elsberg[6] gives his experimental experience in this field. He states that it is possible to innervate a muscle after it is artificially paralyzed. It is not possible to hyperinnervate a normal muscle supplied by its proper motor nerve.

Since February, 1916, the author, with the assistance of W. C. Cunningham, has been conducting experiments on innervation (neurotization) of muscles along the lines described above. The gluteal hamstring group of muscles was deprived of its motor nerve supply. The anterior tibial nerve was divided close to the knee and then implanted into the paralyzed muscle belly. Owing to an epidemic among the operated rabbits, only 3 out of 13 furnished

any positive findings. In fact, it was not until February, 1917, that a rabbit was obtained in which stimulation of the implanted nerve trunk evoked a normal strong contraction in the previously paralyzed muscle; this response was as strong as that obtained from stimulation of normally connected motor nerve trunks in the vicinity. This finding was repeated and confirmed at the end of May, 1917, the animal was killed and the muscle in the vicinity of the implanted nerve was examined for the author by Dr. J. H. Globus, who used the gold chloride precipitation method. The appended figures (1, 2 and 3), show branchings of the implanted nerve as well as motor nerve endings. Similar findings were subsequently obtained in two other animals. One showed a weak but definite response* at the end of 4 weeks, and a normal, strong response at the end of 12 weeks. The other showed a definite response at the end of 12 weeks.

From the foregoing experimental work of others as well as the author's—in which the same procedure has been applied to different groups of muscles in different species of animals with the same result—it seems fairly well proven that a recently paralyzed muscle can be innervated by implantation of a motor nerve. This may be the identical nerve which originally supplied the paralyzed muscle *or some other motor nerve.*

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THE RELATION OF THE ILIOHYPOGASTRIC NERVE TO THE RADICAL CURE OF INGUINAL HERNIA *

AN EXPERIMENTAL STUDY OF THE PHYSIOLOGY OF THE NERVE

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AT a meeting of the New York Surgical Society, held November 11, 1914, Dr. Charles N. Dowd[1] read a paper entitled "Preservation of the Iliohypogastric Nerve in Operation for Cure of Inguinal Hernia." This paper created an unusual amount of interest. Obviously, the necessity of preservation of any normal anatomical structure is so evident, that the plea which Dowd makes seems almost unnecessary. However, in the discussion of this paper, a divergence of views arose as to the reasons for preserving the nerve. Most of the members of the Society advocated the preservation of the nerve, because there did not appear any reason why it should be destroyed. A few members, notably Taylor, Vosburgh, Woolsey, and Moschcowitz, expressed their belief that that part of the iliohypogastric nerve exposed in the operation for the radical cure of inguinal hernia was purely sensory, and that its injury, more particularly its inclusion in the suture line, was occasionally followed by an annoying neuralgia.

Dowd[2] was evidently not convinced by the opinion of those who dissented from him, because less than a month later, namely at the December 9, 1914, meeting of the New York Surgical Society, he offered additional evidence to maintain his contention. In discussing the new evidence, I stated that the results of a few experiments I carried out did not agree wholly with the results of similar experiments in Dowd's hands. In order to convince myself of the soundness of my views, I have instituted a complete reinvestigation of this matter.

In preface I shall say that the attempt at solution of our problem was not as simple as it appeared to be at first blush. Indeed, I soon learned that the problem was so involved that it was impossible for me to carry it out without assistance. I therefore desire to express my cordial appreciation of the service of my collaborator, Dr. Harold

* Read before the New York Surgical Society, February 14, 1917.
[1] Dowd: ANNALS OF SURGERY, vol. lxi, p. 204.
[2] Dowd: ANNALS OF SURGERY, vol. lxi, p. 483.

Neuhof, who carried out all of the animal experiments, and to other members of the Surgical Laboratory of the College of Physicians and Surgeons, notably Dr. Clark and Dr. Cunningham.

The subject may be discussed from two viewpoints, namely: (1) anatomy; (2) physiology.

(1) ANATOMY

A little reflection will very quickly show that the crux of the matter centres around the question as to whether that part of the iliohypogastric nerve which is ordinarily exposed in any one of the conventional operations for the radical cure of inguinal hernia is sensory, or motor, or mixed. Anatomists, however, are very obscure upon this point; most of them give but a very meagre description of the nerve, and not a single text-book is clear about the function of that part of the nerve which is under discussion. Finally, it must be also added, that the variations of the nerve, or, better said, the relationship between the iliohypogastric nerve and its two neighbors, namely, the twelfth intercostal and the ilioinguinal, are admittedly too numerous to admit generalizing deductions.

The consensus of opinion amongst anatomists appears to be that the iliohypogastric nerve is composed of nerve fibres which arise from the twelfth dorsal and first lumbar segments of the cord, and that frequently it arises in common with the ilioinguinal nerve. After emerging from the psoas muscle the nerve runs downward and forward in front of the quadratus lumborum, until it reaches the posterior aponeurosis of the transversus abdominis, and perforates the latter above the crest of the ilium. It then runs forward between the transversus abdominis and the internal oblique muscle, more or less parallel with its inferior fibres, and at a varying distance above the inferior edge of this muscle, until it reaches the linea semilunaris.

Most anatomists state that in the "posterior" part of its course, the iliohypogastric nerve gives off muscular branches to the transversus abdominis, and to the internal and external oblique; most anatomists are also agreed upon the fact that above the middle of the crest of the ilium, the nerve gives off a lateral cutaneous branch, which pierces the external oblique muscle, and descending over the crest of the ilium, is distributed to the integument over the gluteal region. After the main trunk of the nerve has reached the semilunar line, that is, slightly above the external inguinal ring, it pierces the aponeurosis of the external oblique, and is distributed to the integument covering the hypogastric region.

It is also conceded, that while the distribution of the iliohypogastric nerve as above outlined seems to be perhaps the one most frequently encountered, there are also numerous exceptions. The one most frequently met with bears a relation to the distribution of the ilioinguinal nerve; there appears to be a compensatory relationship between the two nerves,

i.e., in some cases the terminal portion of the iliohypogastric nerve is small, and then the ilioinguinal nerve is large, and *vice versa*. There are also frequently found communicating branches between the two.

The description of the iliohypogastric nerve, as I have just given it, is, so to speak, a composite picture of the nerve, derived from my own studies and consultations with the best authorities. So much is conceded by Dowd. Thus far, therefore, we meet upon common ground.

As a matter of fact the only difference of opinion centres around the question as to whether the iliohypogastric nerve sends any important nerve supply into the internal oblique within the zone of our operation. Most anatomists are agreed upon the point that the nerve in the posterior part of its course sends motor fibres into the lower part of this muscle. Dowd also infers as much when he makes the statement that "fibres are given off from these nerves as they course *through* (italics mine) the muscle. These fibres can be seen if careful dissection is made." Our operative field, however, is at a considerable distance from the point where the nerve pierces the muscles; and in our operative field the nerve merely lies on top of the internal oblique muscle, covered by a delicate fascia.

One further statement of Dowd regarding the more minute anatomy of the nerve requires at least a passing comment. It is the following: "Serial microscopic sections have also been made and they show the small fibres of the nerve between the muscle bundles and the main trunk." It appears to me that this statement is somewhat ambiguous, and for the following reasons: First, that to be of some value as an argument, that these are motor nerves, these histological data are altogether inconclusive; on the contrary it would be necessary to show by serial sections that these nerves are directly traceable into the main trunk; second, because no proof is brought forward, nor for that matter can be brought forward, as to whether these nerve fibres are motor or sensory.

(2) PHYSIOLOGY

To the uninitiated it doubtlessly appears that the establishment of the fact as to whether a given nerve is sensory or motor is a very simple matter. All that appears to be necessary would be to apply a faradic current; if the muscle attached to the nerve contracts, it is a motor nerve; if it does not contract, it is a sensory nerve. As a matter of fact, this is one of the proofs brought forward by Dowd, in order to prove his contention, and I confess, that for awhile I was under a similar impression I determined, nevertheless, to test this matter for myself. I therefore made the following experiments in a number of consecutive cases. Well towards the outer part of the operative field the iliohypogastric nerve was carefully dissected free from the underlying internal oblique muscle, for a distance of one to two centimetres, and a piece of sterilized rubber tissue drawn under-

neath it. The function of the nerve was then tested, first with a mild, then with a medium, and finally with a strong faradic current, by means of a specially constructed sterilizable electrode. In my first two cases no contraction whatsoever was obtained; whereupon I hastily jumped to the conclusion that the experiment was an absolute proof of my contention, that the iliohypogastric nerve was a sensory nerve. In the next case, however, I did obtain contractions, and subsequently the results were either positive or negative without apparent reason.

In the next series of experiments I exposed and liberated the nerve in a similar manner, and then deliberately divided it; both ends were then stimulated in the same manner with a faradic current of varying intensity. Again my results were indecisive. Finally I reached the conclusion, that the results depended mostly upon the moisture within or upon the surface of the nerve, and that the current was conducted upon the moisture. Even this had to be tested out, and I did so by sending a faradic current into the muscle on a piece of dry and a wet silk thread. I found that contractions were obtained only when the latter was used. I have related these experiments not to prove my preconceived notions or to disprove the contentions of Dowd, but merely to show that these and similar experiments are absolutely unconvincing.

I next determined to test the matter out by deliberate division of the nerve in an actual operation, in order to determine the end results. All these cases were followed out long enough to enable me to state definitely that no harm resulted therefrom, and that a perfect end-result is maintained. This experiment may also serve to answer the contention, that very important trophic nerve fibres are given off from the iliohypogastric nerve to the internal oblique. Incidentally I may mention that the entire subject of the importance of trophic nerve fibres to muscles is so involved that only speculative views are current.

To recapitulate, the component elements of the entire problem are the following:

1. It is conceded that at its origin the iliohypogastric nerve is a mixed nerve.

2. It is conceded that its termination in the skin is purely sensory.

3. It is conceded that in its posterior part it supplies motor filaments to the internal oblique and transversalis muscles.

4. Granting these three propositions, it follows also that in some part of its course the iliohypogastric nerve ceases to be a mixed nerve and becomes purely sensory. The question, therefore, is where is that point, and, more particularly, is that point proximal or distal to its exposure in our operation for inguinal hernia?

I have already pointed out the fallacies of the methods hitherto pursued, especially in my hands. Therefore, after consulting with

Prof. Lee, of the Department of Physiology, and with Prof. Tilney, of the Department of Neurology, of the College of Physicians and Surgeons, the conclusion was reached, that the only way to prove or disprove my contention, was by a rather complicated animal experiment.

A little reflection will show that the only way to prove the problem experimentally was to cause a degenerative process in the peripheral distribution of the nerve; and the simplest method by which to attain such a degeneration is by a section of the nerve.

Further reflection will also show that in order to be of value the nerve section must be made in such a manner that either the sensory or the motor part of the nerve will degenerate, but always to the complete exclusion of the other. A study of Fig. 1, illustrating diagrammatically a peripheral nerve with the corresponding segment of the spinal cord, shows that a section of the nerve can be made at three different points.

1. A section made at 1 will be of no value, for the reason that the entire nerve distal to the section, namely, both motor and sensory, will degenerate, because both portions have been separated from their centres, which for the sensory fibres is in the gamglion upon the sensory root, and for the motor fibres in the gray matter of the anterior horn of the spinal cord. It is evident, therefore, that our section must be made upon a part of the nerve before its sensory and motor portions have become united.

2. Similarly it would be absolutely of no value to divide the posterior nerve roots at 2 (Fig. 1) (a comparatively easy operation); because after such a section none of the peripheral nerve would degenerate, for the reason that neither the motor nor the sensory part of the nerve has been separated from its centres.

3. There remains, therefore, only the third possibility, namely, to make a section of the anterior nerve roots at their emergence from the anterior horns; as is indicated at 3 of Fig. 1.

The rationale of the operation is the following:

(*a*) Such a section would cause a degeneration of all the peripheral part of the motor nerve, because it has been separated from its centre in the gray matter of the anterior horn of the spinal cord.

(*b*) Such a section would cause no degeneration in the peripheral sensory part of the nerve, because that part of the nerve is still in connection with its centre in the gamglion upon its root.

(So delicate is this test that even an accidental injury of the posterior nerve root in the course of the operation would have no deleterious effect upon the experiment; all that such an injury could do would be to cause a degeneration of the corresponding nerve fibres in the spinal cord.)

(*c*) Assuming now that the animal survived the operation for a period of time sufficiently long to have caused a degeneration of the nerve, it will be necessary to examine different portions of the nerve for degenerative changes. From the nature of the experiment it also

follows, that all that portion of the nerve which is degenerated must be motor; and whatever is not degenerated must be sensory.

(*d*) In order to prove our contention beyond any doubt, it is absolutely important that every one of the anterior roots which enter into the formation of the iliohypogastric nerve be divided: because it is also perfectly possible that some motor fibres might have escaped degeneration in the peripheral part of the nerve, and so might be mistaken for sensory nerve fibres. Even in the human being the forma-

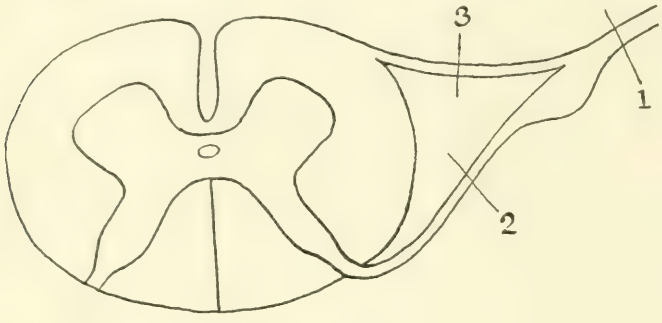
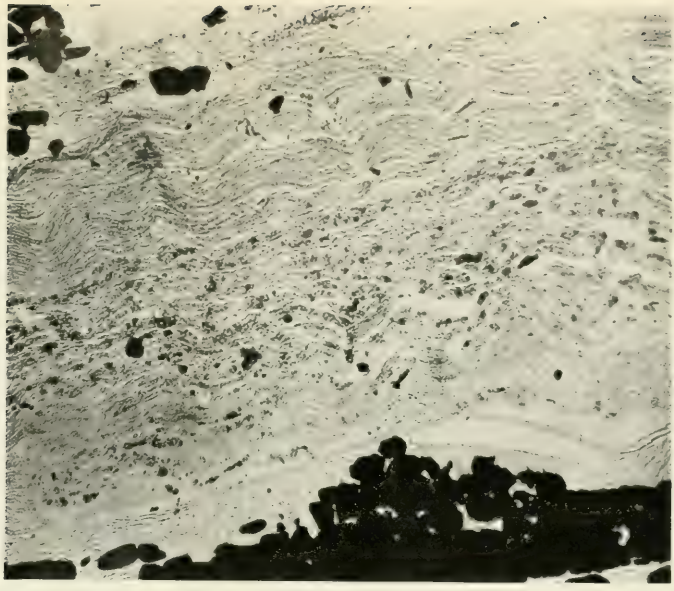


FIG. 1.

tion of the lumbar plexus is not absolutely uniform; as already stated, however, the consensus of opinion is, that the iliohypogastric nerve is a branch of the first lumbar nerve, and receives also fibres from the last intercostal, so that all that would be necessary in the human being would be to divide these two roots. In the dog, however, there appear to be so many variations, that to be absolutely certain one would also have to divide at least the two adjoining nerve roots, namely the eleventh dorsal and second lumbar; and to be absolutely certain it was decided to divide at least five roots. This, of course, increases the risk of the operation and also the dangers of infection; and it is particularly on this account that our absolutely successful experiments are limited to two.

Five experiments were performed. The results, as already stated, were satisfactory in only two. It was found that a very long exposure of the cord was required to divide five roots in the region in question, and that one was not always successful in the division of the anterior roots. So much of the bony support of the spinal column was necessarily removed, that some bowing of the back was unavoidable. The operation partakes necessarily of a very major character. These remarks will serve as an explanation for the three unsatisfactory results. One dog died two days after operation. In another there was a wide separation of the wound, exposure of cord, and incomplete division of the nerve roots. In a third case the roots were incorrectly selected



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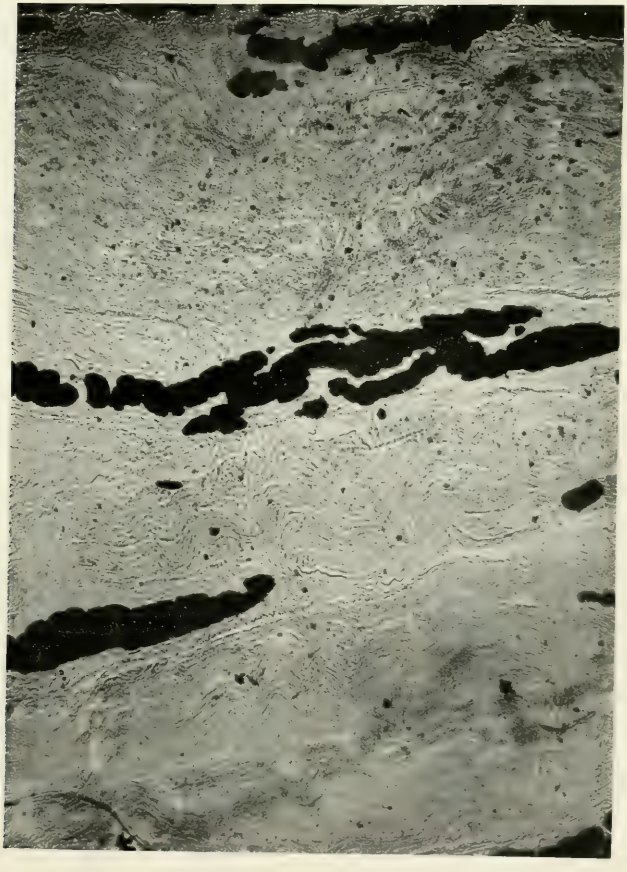

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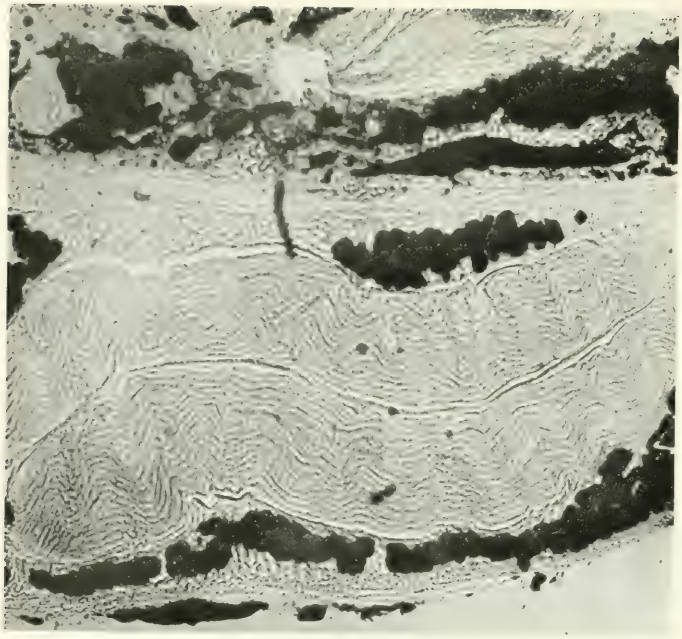

FIG. 4.

FIG. 5.

FIG. 6.

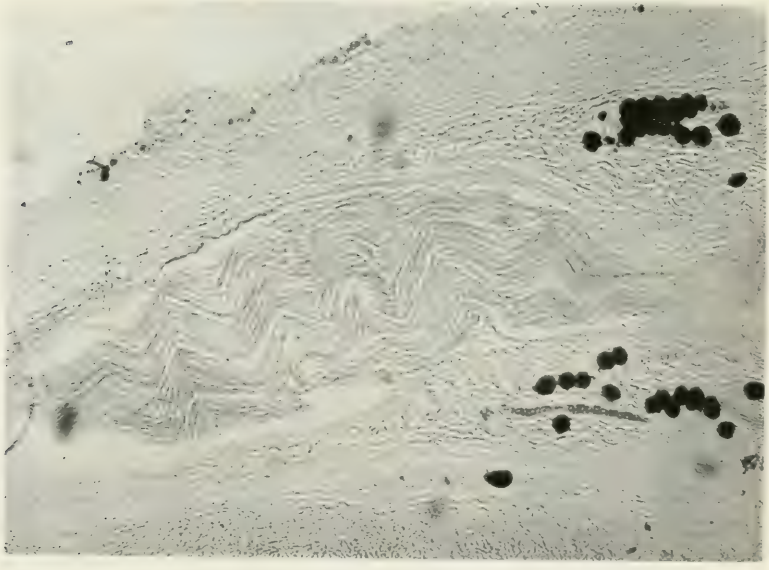

FIG. 7.

and incompletely divided. It should be clearly understood, however, that in none of these unsatisfactory experiments did examination of the iliohypogastric nerve in the inguinal region show any trace of degeneration. It should be also stated, that in our opinion, a single satisfactory experiment in degeneration after root section is sufficient to establish the point in question, when as many as five roots (two above and two below the main, if not the entire source of the iliohypogastric nerve) are divided.

The successful experiments are the following:

Experiment 1.—Dog 88, good sized male. Operation, January 5, 1916. Dog in prone posture. Median incision over the lower dorsal and upper lumbar spine. Spinous processes of the eleventh and twelfth thoracic, first, second, and third lumbar vertebræ isolated by incising and stripping back the musculature on both sides. These spines and their laminæ were removed beyond the articular junctions. A long and wide exposure of the dura was thereby obtained. Tension sutures were placed through the dura, and the latter incised between them. Dura slit up and down with a grooved director. Some cerebrospinal fluid escaped. It was planned to divide the left anterior roots; therefore the left dentate ligaments were divided in order to mobilize the cord. The anterior roots were now divided by slipping a fine scissors under the posterior roots. Each division was followed by muscular contraction and rather free bleeding. The roots divided were the eleventh and twelfth dorsal, first, second and third lumbar. As the dura could not be sutured without constricting the cord, a strip of aponeurosis from over the erector spinæ, 2 cm. wide and of appropriate length, was sutured into the dural gap with fine silk. Layer suture of the muscles, aponeurosis of the erector spinæ and skin. Cotton collodion dressing.

Post-operative Course.—Primary union. For several days both hind legs were weak and dragged on walking. Reflexes were normal, however, and bladder and rectal control appeared undisturbed. Normal power in legs returned about eight days after operation. Animal sacrificed with chloroform, January 24, nineteen days after operation.

Post-mortem Examination.—Firm union of tissues. No evidence of infection. The cord is overspread by a dense layer of connective tissue, loosely attached to it. The dura is adherent to this layer only at the cut margins. Cerebrospinal fluid not encountered in the field of operation. No evidence of injury to the cord. The roots divided were again verified to be the eleventh and twelfth dorsal, the first, second, and third lumbar. The eleventh dorsal and second lumbar divisions did not completely separate the ensheathing connective tissue.

The iliohypogastric nerve was exposed throughout its entire course. (Right here we wish to mention, that in numerous dissections we have found that the peripheral course and distribution of the iliohypogastric nerve in the dog is exactly the same as in the human being.) No gross changes were seen. Sections were taken from various parts of the nerve and labeled: (*A*) From the upper part of its course; (*B*) from the middle part of its course; (*C*) from that part of its course which lies in the inguinal region.

Microscopic Examination.—Surgical Pathology No. 3791. *A*, *B*, and *C*. Marchi's stain. Many slides made from each section, cut longitudinally.

Section *A* (Fig. 2) shows moderate amount of segmentation of the fibres and granular deposition of fat in approximately one-half of the longitudinally sectioned nerve. The other half shows no trace of degeneration.

Section *B* (Fig. 3) shows the same picture as *A*, with degeneration to the same extent and limitation.

Section *C* (Fig. 4) shows absolutely no trace of degeneration; normally staining nerve.

Experiment 2.—Dog 78, female, fair size. Operation, December 22, 1915, same procedure as in previous experiment. There was considerable oozing from the divided musculature, controlled by pressure. The posterior spinal vein was slightly injured in opening the dura, but a ligature was not required. The left anterior eleventh and twelfth dorsal and first, second, and third lumbar roots were divided. (The corrected root division is given in the post-mortem examination.) The dura was not sutured, and fascia was not implanted into the defect. Layer suture of the wound.

Post-operative Course.—Slight separation and infection of the upper part of the wound. No evidence of cord injury. Animal sacrificed with chloroform on January 7, 1916, sixteen days after operation.

Post-mortem Examination.—Thin inflammatory membrane over the upper part of the cord exposed at operation.

The left anterior roots were found completely divided. They were the tenth, eleventh, and twelfth dorsal, and first and second lumbar. No gross changes were seen in the left iliohypogastric nerve.

Sections were taken as in the previous experiment and similarly labeled *A, B* and *C*.

Microscopic Examination.—Surgical Pathology No. 3813, *A, B,* and *C*. Marchi's stain. Sections cut longitudinally.

Section *A* (Fig. 5): In different slides moderate to severe segmentation and fragmentation of the nerve fibres into thick zones, with a mass of non-degenerated fibres in the middle. The total diameter of the degenerated portion approximately equalled that of the non-degenerated mass of nerve bundles.

Section *B* (Fig. 6): Approximately one-half of the nerve shows moderately advanced degeneration.

Section *C* (Fig. 7): No evidence of degeneration; normally staining nerve.

These two successful experiments therefore prove the following:

1. The posterior part of the iliohypogastric nerve is a mixed nerve, *i.e.*, both motor and sensory.

2. That part of the iliohypogastric nerve which is exposed in the conventional operation for the radical cure of inguinal hernia is purely sensory.

RÉSUMÉ

1. That part of the iliohypogastric nerve which is exposed in the conventional hernia operation is to be preserved, because there is no necessity for dividing it, and also because its complete division will be followed by a temporary anæsthesia of the hypogastric region. After a while regeneration of the nerve occurs and the anæsthesia disappears.

2. The nerve should be protected from a careless inclusion in the suture line. Such a careless inclusion is likely to be followed by a neuralgic pain.

3. A careless division of the nerve is not followed by a local paralysis of the internal oblique muscle and therefore has no bearing upon the radical cure.

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A HISTOLOGICAL STUDY OF THE CIRCULAR SUTURE OF THE BLOOD-VESSELS

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The purpose of this study is to obtain some light on the repair of sutured blood-vessels, and to determine upon a simplified technic which would render the circular suture of blood-vessels practicable in general surgery.

The first recognized successful suture of a blood-vessel was performed by Jassinowski, in 1889. He made use of interrupted sutures. Burci, in 1890, and Silberberg, in 1897, report similar results. The same year Murphy reported his method of invagination. Doerfler in 1889 first used the method now employed, the essential features of which were the use of fine round needles and fine silk, and the continuous sutures embracing all the coats of the vessel. Hirsch, Brian and Jaboulay were followed in 1900 by Payr, Bougle, Clermont, Tomaselli and Salvia. Berard and Carrel began to study end-to-end arteriovenous anastomosis in 1902. During the next years Jensen and Hoepfner and Floresco pursued the same studies. In 1905 Carrel and Guthrie had favorable results from their method of continuous sutures penetrating the media and intima. Other workers in blood-vessel suture were Ullman and von Decastello, Stich, Jeger, Borst and Enderlen, Lespinasse, Villard and Tavernier, Yamanoüchi, Horsley and Bernheim.

The results of arterial circular suture in animals by Borst and Enderlen, Yamanoüchi, Ward, Stich and Carrel by Carrel's method show 74.2 per cent. successes in a total of 148 cases. Sofotereff says that in 352 cases operated upon by the Carrel method, there were 49.8 relative percentage of successes, 15.5 per cent. by the Murphy method, and 17.6 per cent. by the Payr method of invagination with magnesium rings.

Of the methods described, Jeger considered Carrel's technic the best for the surgeon who has made a specialty of blood-vessel suture, but was inclined to believe that the Payr method, on account of its simplicity, would find a field of usefulness in war surgery.

Carrel's technic is as follows: "The round straight needles, Kirby No. 16, threaded with fine silk and sterilized in vaseline, are used. The

operative field is circumscribed by a black Japanese silk towel on which the fine threads can be easily seen. The temporary hæmostasis is secured by elastic clamps, forceps or rubber bands. The vessels are severed and the adventitia removed from the end of the vessels. The blood is washed out not only from the vessels but also from the operating field. The vessels and the surrounding parts are then covered with warm vaseline.

"The vessels to be sutured must be approximated without much tension. They are brought together by three retaining stiches, introduced at three equidistant points of their circumference. By traction on these threads, the circumference of the vessel can be transformed

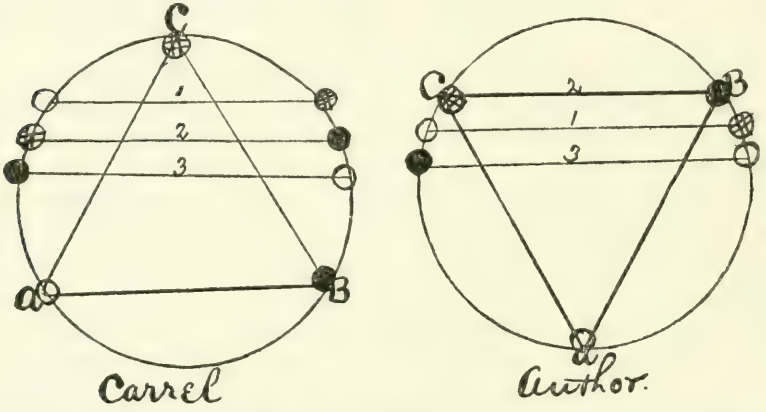

FIG. 1.—AO, first retaining and traction suture, also starting point of circular suture; B● second retaining and traction suture; C●, third retaining and traction suture. Lines 1, 2 and 3 (left figure) indicate the relative position of the corresponding sides of the triangle during the suture by Carrel's method. Lines 2, 1 and 3 (right figure) indicate the relative position of the corresponding sides of the triangle during the suture by author's modification.

into a triangle. The first retaining thread is used as a continuous suture, uniting the three sides of the triangle. During the suture great care is taken to approximate accurately the cut surfaces of section of the walls.

"In arteriovenous anastomosis the vein is generally larger than the artery. After the ends of both vessels have been approximated by the three retaining sutures with some of the stitches of the continuous suture, a relatively larger portion of the vein is taken up than of the artery, thus the caliber of the vein is progressively reduced and a good union takes place. In side-to-side anastomosis, both vessels are brought near one another, and an ellipse resected from the contiguous walls. A temporary provisional suture is introduced into the posterior margin of both vessels, but is not tied. Two retaining sutures unite either end of the openings. The ends of the retaining stitches are on the external

surface of the vessels. The union is completed by a continuous suture. Leakage during the first minutes after the circulation is restored is controlled by gentle pressure with gauze. After two or three minutes the sponges are removed, and, if some hemorrhage persists, one or two complementary stitches are added."

I believe that it is important to avoid the use of instruments in handling the severed ends of the vessels. The adventitia is drawn over the end of the vessel with fingers well oiled with paraffin, and severed with scissors.

The third side of the triangle with Carrel's method is made accessible for suture only by twisting the vessels for a distance of 180 degrees. By introducing the first retaining stitch on the posterior side so that the triangle formed by the three retaining stitches will have its apex downward, it was found that the vessels were twisted only for an arc of a quarter of a circle or 90 degrees. The importance of this feature of the technic is particularly emphasized in an attempt to anastomose the shorter vessels, such as the renal and splenic. I find that liquid paraffin is more easily handled than vaseline, especially during cold weather.

While the eversion of the vessel ends emphasized by most of the experimenters is quite essential, this detail should not be exaggerated, particularly in the anastomosis of arteries where the histological reconstruction of the continuity of the vessel should be sought for in order to assure a perfect functional result.

The results obtained seem to prove that coaptation of the respective layers of the vessel wall can be accomplished with a simple running suture. This is illustrated in a number of the specimens which attains the object with a minimum amount of cicatrix and with an almost perfect restoration of the normal integrity of the vessels. A restoration of the intima is most essential in order to eliminate as far as possible the dangers of an occluding thrombus. It cannot be denied, however, that this can be accomplished without the practice of the mattress or double mattress suture advocated by Horsley. This is shown in the histological study of the specimens. The objection to the mattress suture on theoretical grounds would be that it has a tendency to evert the severed ends of the layers of elastic tissue and muscularis. This tendency even goes so far as to eliminate the possibility of their re-entering into the continuity of the vessel wall. I have found in side-to-side anastomosis that the use of the three-bladed clamp of Jeger very much simplifies the procedure. After the vessels have been fenestrated, the introduction of an additional temporary traction suture in the anterior margins

of the openings facilitates the use of the straight needle without inflicting injury upon the exposed intima. These temporary sutures should not be tied and are readily removed after the continuous suture has been completed. The traction is produced with the weight of the serrefines.

The histological studies of the process of healing of the circular suture of vessels have been as follows:

Carrel in 1907 reported findings after autotransplantation of jugular vein to carotid. He stated that the walls were thickened and, *vice versa,* in the transplantation of artery into vein the walls become attenuated so that it might be said that the transplant eventually shows changes in its structure in accordance with the blood-pressure to which it has been subjected. Stich, Makkas and Dowmann show the thickening of the intima and proliferation of the endothelium.

Fischer and Schmieden report histological findings in transplantation of vein to carotid removed from a dog after eighty-six days. They found a marked thickening of the media due to a hypertrophy of the muscularis and connective tissue invasion. The intima was somewhat thickened over the line of suture. They also found among the spindle-cell proliferation of the intima, some cells that resembled smooth muscle cells. They note the absence of elastic fibres in all of their specimens.

Capelle states that he found proliferation of the intima with very little changes in the media or adventitia. W. Ward found that homotransplantations, similar to heterotransplantations, eventually become absorbed. The elastic fibres, however, remain intact.

Borst and Enderlen in an autotransplantation of carotid artery after 132 days report that the elastic fibres were replaced by connective tissue. There were small areas of necrosis in the media. The sutures were surrounded by granulation tissue, containing phagocytes and giant-cells. The vasa vasorum were increased in number and somewhat thickened. The elastic fibres end at the scar and show a tendency to divide into bundles. A few very delicate newly formed elastic fibres were present in the scar itself. The muscularis showed marked atrophy.

Ribbert is quoted by Borst and Enderlen as saying that a homotransplant seems to be able for a short time at least to withstand the biological differences in body juices between the donor and host. He believes that the transplant will begin to show evidences of absorption as soon as its own tissue fluids are exhausted.

Jacobsthal claims that he saw new elastic fibres appear as early as 12 days, Borst and Enderlen, 14 days, and Faykiss in 3 weeks.

Borst and Enderlen believe that the union of the vessels evidently

takes place by scar tissue. Minute small areas of necrosis have been observed in the media. Archibald Smith has also reported such a finding. "There is some danger of aneurismal formation following the cutting out of the silk sutures when drawn too tightly or when introduced under too great tension. The triangular-shaped groove formed by the eversion of the two vessel ends becomes covered with endothelium. The endothelium showed proliferation of a spindle-cell variety and can be observed within twenty-four hours. The sutures were surrounded by polymorphonuclear leucocytes and buried in the new tissue formation. Elastic fibres and muscle fibres disappear in the everted portion of the vessels while the elastic fibre of the media near the scar undergoes degeneration. A few delicate elastic fibres make their appearance later in the scar itself. We cannot therefore say that all the elements of the vessel wall are absolutely restored, but that scar tissue enters into the process of healing."

According to Aschoff, the vascular wounds are closed immediately by fibrin and platelets. "The degree of thrombosis depends upon the amount of traumatism inflicted, secondly upon the nature of the wall of the vessel (arteriosclerosis), and thirdly, the state of the circulation. The process is followed by a cellular proliferation which infiltrates and covers the thrombus. This is followed by invasion of the adventitia and media. The media is the seat of marked connective tissue and very slight muscle cell proliferation. New elastic fibres permeate the scar, especially the outer layers. An absolute restoration of the elastic and muscular tissue of the vessels seems improbable."

According to Yamanoüchi, union takes place by the formation of scar tissue with a partial preservation of the muscle cells, the elastic fibres being somewhat increased in number. He found that homotransplantations of vessels were followed by gradual degeneration and destruction of the transplant which is eventually replaced by connective tissue. The findings in No. 3529 and No. 2753 agree with those of this author.

Borst and Enderlen claim that the muscularis disappears almost entirely from the vicinity of the suture line.

The specimens No. 3846 and No. 3258 in this series show the muscularis well preserved and extending into the line of suture.

The presence of valves in a vein transplant does not necessarily favor coagulation or thrombus formation, as is demonstrated in several of these specimens (see Fig. 10, No. 2477).

The consensus of opinion is that the restoration of the intima is brought about by proliferation of the endothelium.

My specimens in which histological examinations were made include examples of end-to-end or circular sutures, side-to-side anastomosis between artery and vein, the end-to-end arteriovenous anastomosis and the transplantation of segments of vessels:

Experiment No. 40.—Fig. 2. Drawing. Low power. End-to-end suture of carotid. Dog No. 27. Surg. Path. No. 3729. Operation, November 13, 1915. Specimen removed November 22, 1915. Sutured ends separated by ½ mm. of connective tissue on one side; on the other side by 2 mm. This connective tissue at some points is dense; at other points it is loosely constructed. The intima regenerates everywhere. At one point one of the sutures lies within the vessel lumen, and is completely covered by connective tissue, with an endothelial surface. Where there was wide separation of the vessel ends, there is a considerable mass of relatively loose connective tissue on the surface which is covered with intima. In the depths the repaired vessel wall is dense and suggests osteoid structures. In the depths of the suture line at another point, very definite osteoid structure exists. There is a distinct dilatation of the lumen present at the site of the suture line.

Fig. 3. Drawing. End-to-end suture of carotid. Dog No. 27. Surg. Path. No. 3729. Operation November 13, 1915. Specimen removed November 22, 1915. Sutured ends separated by ½ mm. of connective tissue on one side; on the other side by 2 mm. This connective tissue at some points is dense; at other points it is loosely constructed. The intima regenerates everywhere. At one point, one of the sutures lies within the vessel lumen, and is completely covered by connective tissue, with an endothelial surface. Where there was wide separation of the vessel ends, there is a considerable mass of relatively loose connective tissue on the surface which is covered with intima. In the depths, the repaired vessel wall is dense and suggests osteoid structures. In the depth of the suture line at another point, very definite osteoid structure exists. There is a distinct dilatation of the lumen present at the site of the suture line.

Experiment No. 47.—Fig. 4. Drawing. End-to-end suture of carotids. Dog No. 108. Surg. Path. No. 3846. Operation January 20, 1916. Specimen removed February 9, 1916. Cicatricial tissue firmly unites one vessel end to that of the other. One extremity is slightly everted and the other is implanted upon it. The recess is so obliterated by connective tissue that the intimal lining is completely regenerated. The suture line is hardly discernible on account of the merging of the cicatrix with the sutured ends. Smooth muscle cells as demonstrated in a Van Gieson stain infiltrate the cicatrix.

Experiment No. 1.—Surg. Path. No. 2053. End-to-end suture of carotids. Dog. No. 313. Operation April 30. Specimen removed May 27. Strong dense cicatrix joins both ends. The lining membrane completely regenerated. Some bulging of vessel wall at site of cicatrix.

Experiment No. 43.—End-to-end anastomosis of carotids. Eleven days. Dog No. 56. Surg. Path. No. 3765. Operation December 9, 1915. Specimen removed December 20, 1915. Vessel wall on one side shows the ends are in perfect alignment. There is a minimum amount of scar tissue forming the suture line. On the other wall there is an eversion. The recess is filled in with fibrin and leucocytes. Cicatricial tissue firmly unites end of vessel wall to end of vessel wall.

FIG. 2.—Drawing. Low power. End-to-end suture of carotid. Dog No. 27. Surg. Path. No.3729. Operation, November 13, 1915. Specimen removed November 22, 1915. Sutured ends separated by ½ mm. of connective tissue on one side; on the other side by 2 mm. This connective tissue at some points is dense; at other points it is loosely constructed. The intima regenerates everywhere. At one point, one of the sutures lies within the vessel lumen, and is completely covered by connective tissue, with an endothelial surface. Where there was wide separation of the vessel ends, there is a considerable mass of relatively loose connective tissue on the surface which is covered with intima. In the depths the repaired vessel wall is dense and suggests osteoid structures. In the depths of the suture line at another point, very definite osteoid structure exists. There is a distinct dilatation of the lumen present at the site of the suture line.

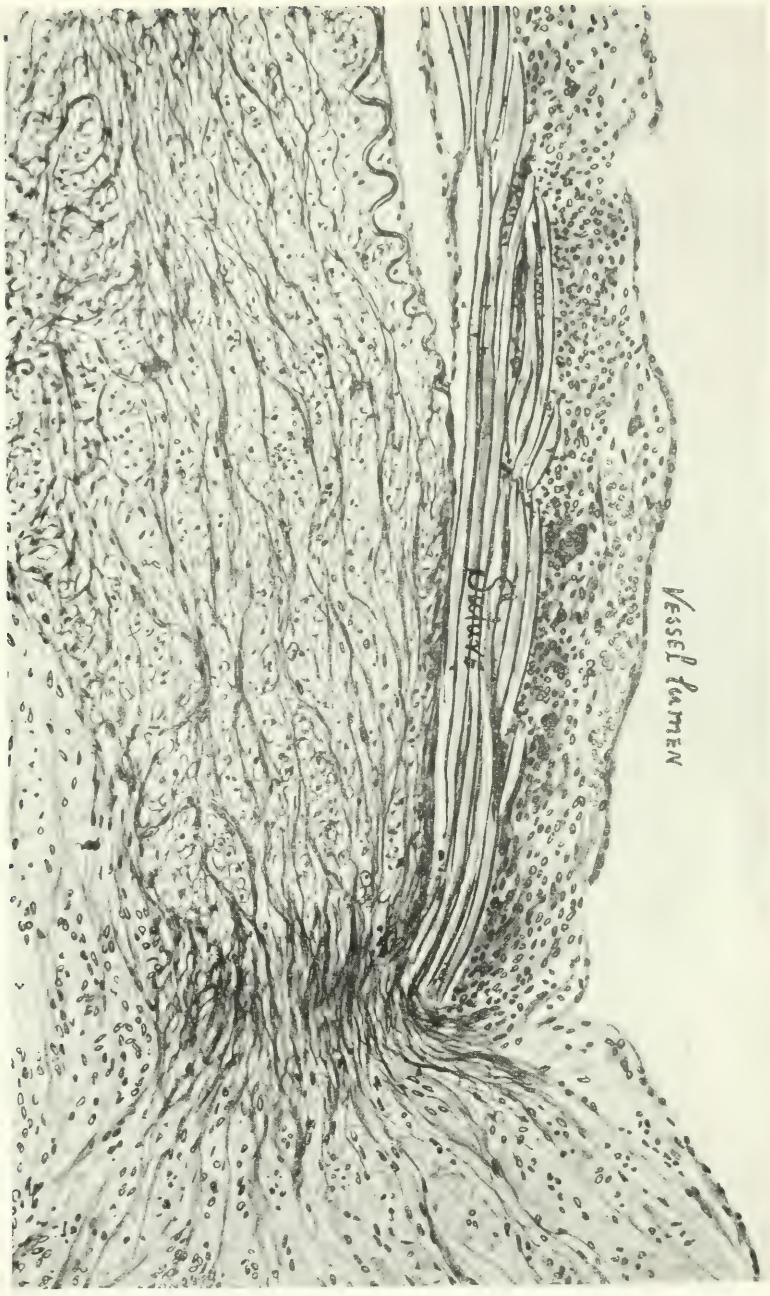

FIG. 3.—Drawing. End-to-end suture of carotid. Dog No. 27. Surg. Path. No. 3729. Operation, November 13, 1915. Specimen removed November 22, 1915. Sutured ends separated by ½ mm. of connective tissue on one side; on the other side by 2 mm. This connective tissue at some points is dense; at other points it is loosely constructed. The intima regenerates everywhere. At one point, one of the sutures lies within the vessel lumen, and is completely covered by connective tissue, with an endothelial surface. Where there was wide separation of the vessel ends, there is a considerable mass of relatively loose connective tissue on the surface which is covered with intima. In the depths the repaired vessel wall is dense and suggests osteoid structures. In the depths of the suture line at another point, very definite osteoid structure exists. There is a distinct dilatation of the lumen present at the site of the suture line.

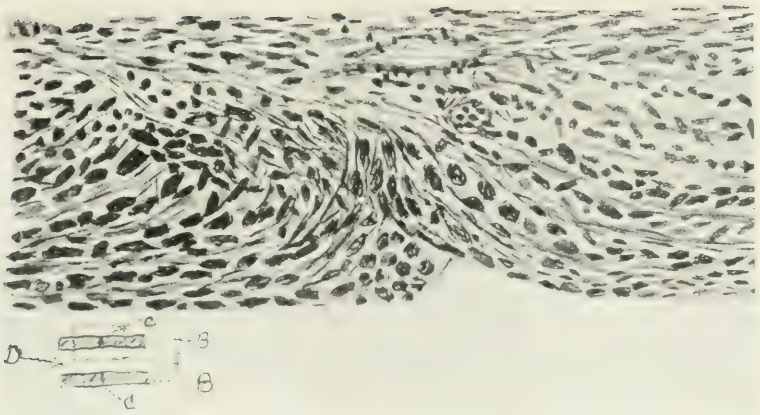

FIG. 4.—Drawing. End-to-end suture of carotids. Dog No. 108. Surg. Path. No. 3846. Operation January 20, 1916. Specimen removed February 9, 1916. Cicatricial tissue firmly unites one vessel end to that of the other. One extremity is slightly everted and the other is implanted upon it. The recess is so obliterated by connective tissue that the intimal lining is completely regenerated. The suture line is hardly discernible on account of the merging of the cicatrix with the sutured ends. Smooth muscle cells as demonstrated in a Van Gieson stain infiltrate the cicatrix.

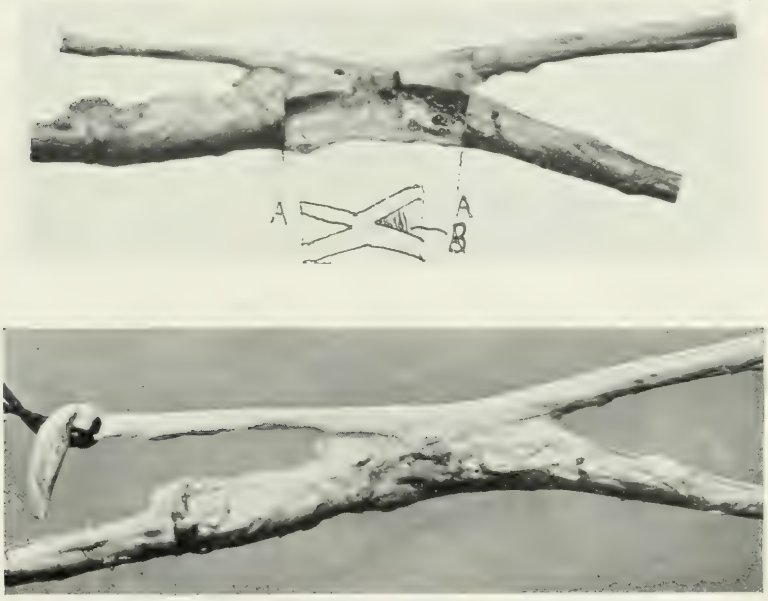

FIG. 5.—Side-to-side anastomosis, jugularis externa and carotid. Surg. Path. No. 3861. Operation June 18, 1915. Specimen removed February 28, 1916.

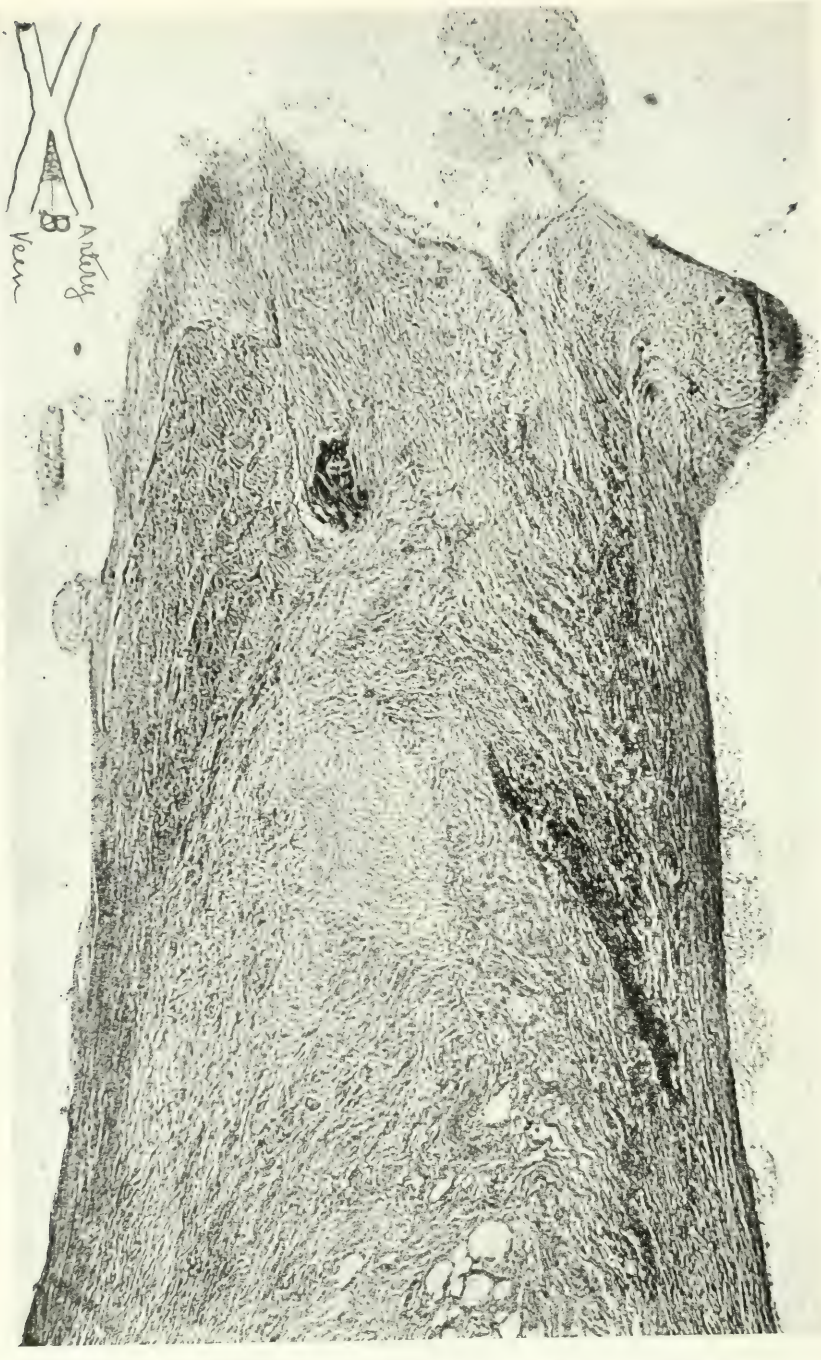

FIG. 6.—Photomicrograph. Side-to-side anastomosis between external jugular and carotid. Dog No. 386. Surg. Path. No. 3861. Operation June 18, 1915. Specimen removed February 28, 1916. Intimal surface joins intimal surface through the opening. Cicatricial tissue joins adventitia to adventitia adjacent to the opening. Sutures are well buried in the media and adventitia.

FIG. 7.—Photomicrograph, mag. 20. Autotransplantation of femoral vein to carotid. Eight days. Dog No. 268. Surg. Path. No. 2382. Space between artery wall and transplant is exceedingly small and made up of proliferating connective tissue. Surface of the transplant is undergoing some form of degeneration. Immediately beneath the wall of the transplant, active proliferation of connective tissue is seen. A suture in the intima is covered by fibrin and reparative connective-tissue cells. Elastic fibres in the transplant are separated into smaller bundles. The wall of the transplant is apparently undergoing degeneration.

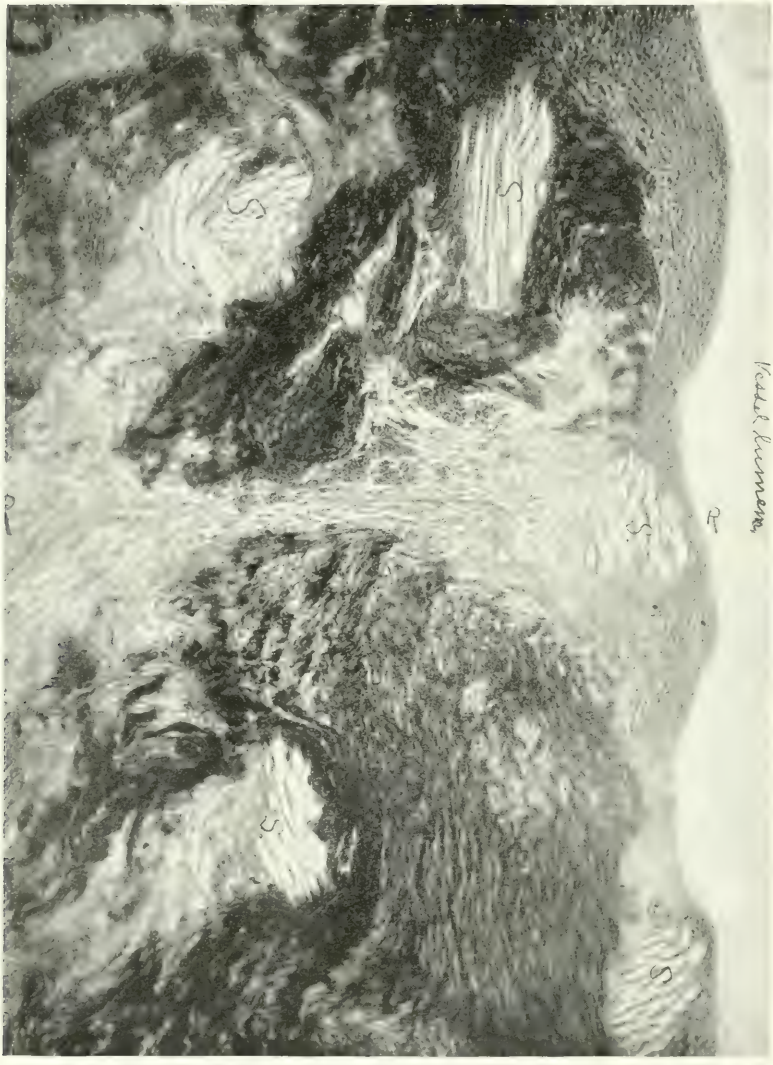

FIG. 8.—Photomicrograph, mag. 300. Autotransplantation of femoral vein to carotid. Eight days. Dog No. 268. Surg. Path. No. 2382. Space between artery wall and transplant is exceedingly small and made up of proliferating connective tissue. Surface of the transplant is undergoing some form of degeneration. Immediately beneath the wall of the transplant, active proliferation of connective tissue is seen. A suture in the intima is covered by fibrin and reparative connective-tissue cells. Elastic fibres in the transplant are separated into smaller bundles. The wall of the transplant is apparently undergoing degeneration.

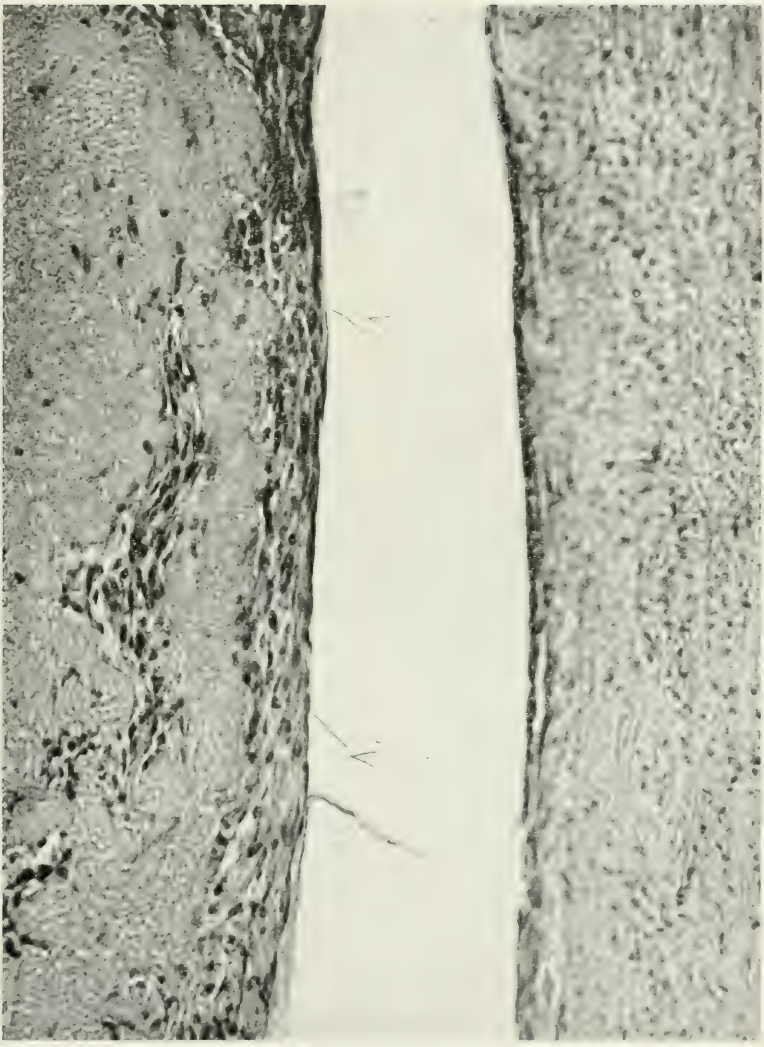

FIG. 9.—Photomicrograph, mag. 415. Autotransplantation of vein into carotid. Surg. Path. No. 2283. Operation January 3. Specimen removed January 17. Vessel partially occluded by coagulum. Surface of coagulum presents connective-tissue cells and apparently no accretion has taken place. Blood coagulum covered by growing fibroblasts also infiltrating coagulum. No further tendency for blood to form a clot in the coagulum which presents a smooth surface as shown here.

FIG. 10.—Photomicrograph, mag. 200. Autotransplantation of jugular to carotid. Two weeks. Dog No. 201. Surg. Path. No. 2340. Specimen removed January 31, 1913. Walls of the vessels are separated by about one millimetre. The interval is filled in by dense connective tissue. Scar tissue is somewhat irregular, but not covered by fibrin, except at one point. A uniform and regular layer of cells covers the cicatricial scar tissue.

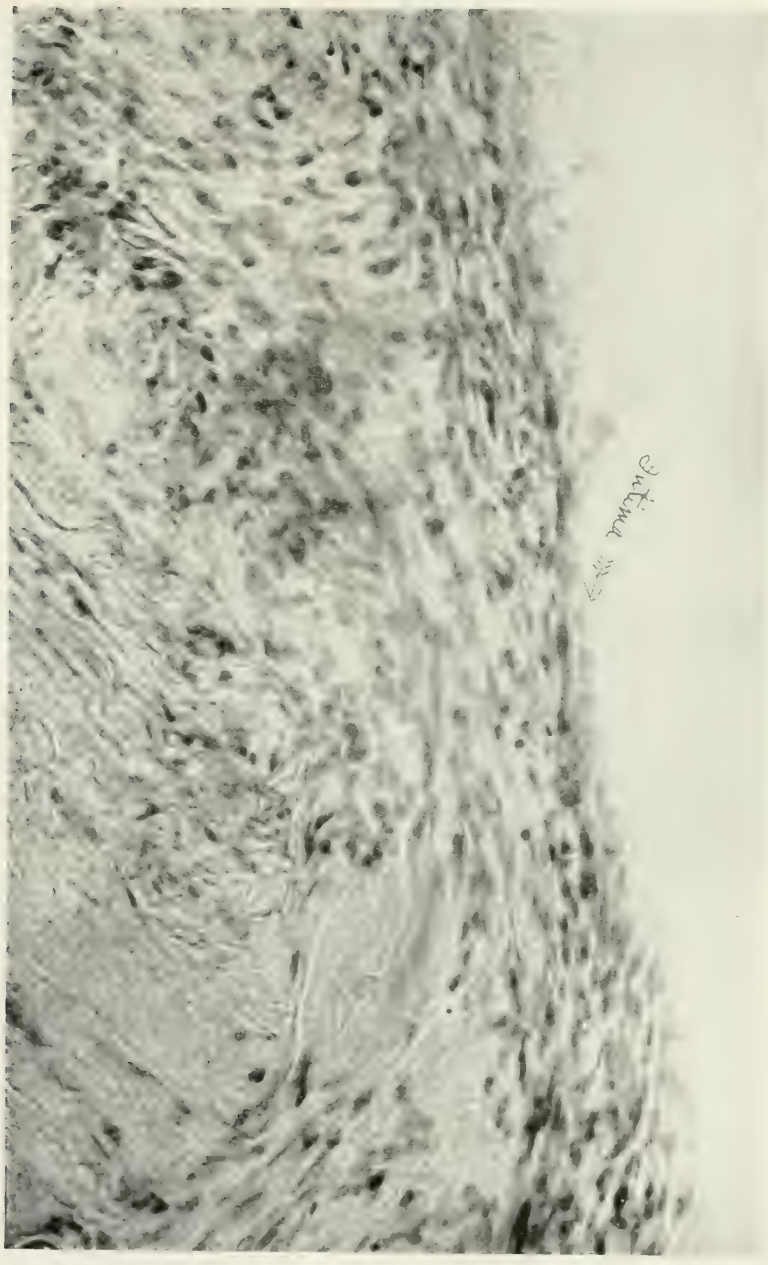

FIG. 11.—Photomicrograph, mag. 415. Autotransplantation of jugular to carotid. Two weeks. Dog No. 201. Surg. Path. No. 2340. Operation January 14, 1913. Specimen removed January 31, 1913. Walls of the vessels are separated by about one millimetre. The interval is filled in by dense connective tissue. Scar tissue is somewhat irregular but not covered by fibrin except at one point. A uniform and regular layer of cells covers the cicatricial scar tissue.

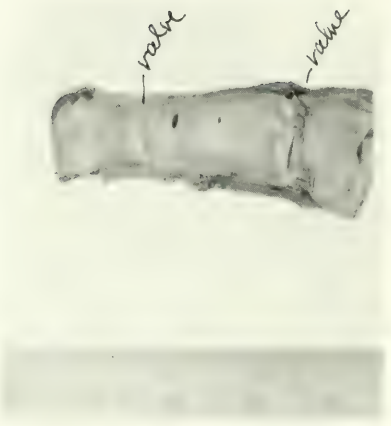

FIG. 12.—Homotransplantation of femoral vein to jugular vein. Surg. Path. No. 2477. Operation April 11, 1913. Specimen removed April 18, 1913. Shows two valves in transplanted vein, one of which encroaches upon suture line.

FIG. 13.—Photomicrograph. Homotransplantation of femoral vein to the jugular. Dog No. 346. Surg. Path. No. 2477. Femoral vein transplanted from donor 178. Operation April 11, 1913. Specimen removed April 18, 1913. Complete union between transplant and jugular. Sutures are *in situ*. Accumulation of leucocytes about sutures. Intima smooth and even throughout. No formation of fibrin on intimal surface. Minute amount of connective tissue between apposed ends of vessels.

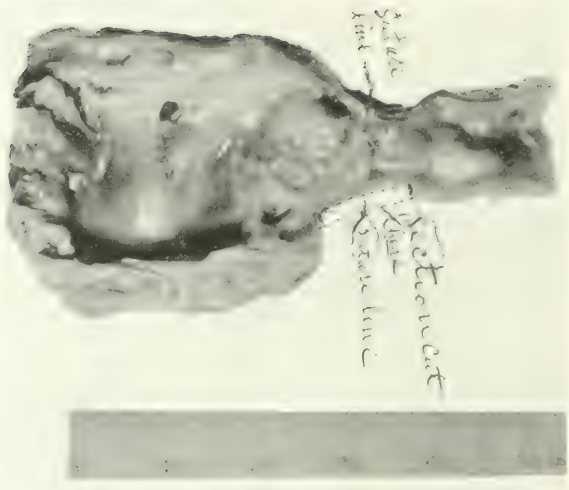

FIG. 14.—Arteriovenous anastomosis of femoral vessels. Male adult, aged thirty-five. Surg. Path. No. 3550.

FIG. 15.—Photomicrograph, mag. 100. Arteriovenous anastomosis (human vessels). Surg. Path. No. 3550. The artery in close apposition with vein, especially in adventitia and media. Mass of connective tissue which has grown beneath the intima reinforces the junction. In the section at points the endothelium is intact. A thin layer of fibrin with a few round-cells in it is in the venous portion of the section.

Experiment No. 35.—Fig. 5. Side-to-side anastomosis. Jugularis externa and carotid. Surg. Path. No. 3861. Operation June 18, 1915. Specimen removed February 28, 1916.

Fig. 6. Photomicrograph. Side-to-side anastomosis between external jugular and carotid. Dog No. 386. Surg. Path. No. 3861. Operation June 18, 1915. Specimen removed February 28, 1916. Intimal surface joins intimal surface through the opening. Cicatricial tissue joins adventitia to adventitia adjacent to the opening. Sutures are well buried in the media and adventitia.

Experiment No. 12.—Fig. 7. Photomicrograph. Mag. 20. Autotransplant of femoral vein to carotid. Eight days. Dog No. 268. Surg. Path. No. 2382. Space between artery wall and transplant is exceedingly small and made up of proliferating connective tissue. Surface of the transplant is undergoing some form of degeneration. Immediately beneath the wall of the transplant, active proliferation of connective tissue is seen. A suture in the intima is covered by fibrin and reparative connective tissue cells. Elastic fibres in the transplant are separated into smaller bundles. The wall of the transplant is apparently undergoing degeneration.

Fig. 8. Photomicrograph. Mag. 300. Autotransplantation of femoral vein to carotid. Eight days. Dog No. 268. Surg. Path. No. 2382. Space between artery wall and transplant is exceedingly small and made up of proliferating connective tissue. Surface of the transplant is undergoing some form of degeneration. Immediately beneath the wall of the transplant, active proliferation of connective tissue is seen. A suture in the intima is covered by fibrin and reparative connective tissue cells. Elastic fibres in the transplant are separated into smaller bundles. The wall of the transplant is apparently undergoing degeneration.

Experiment No. 5.—Fig. 9. Photomicrograph. Mag. 415. Autotransplantation of vein into carotid. Surg. Path. No. 2283. Operation January 3. Specimen removed January 17. Vessel partially occluded by coagulum. Surface of coagulum presents connective tissue cells and apparently no accretion has taken place. Blood coagulum covered by growing fibroblasts also infiltrating coagulum. No further tendency for blood to form a clot in the coagulum which presents a smooth surface as shown here.

Experiment No. 7.—Fig. 10. Photomicrograph. Mag. 200. Autotransplantation of jugular to carotid. Two weeks. Dog No. 201. Surg. Path. No. 2340. Specimen removed January 31, 1913. Walls of the vessels are separated by about one millimetre. The interval is filled in by dense connective tissue. Scar tissue is somewhat irregular, but not covered by fibrin, except at one point. A uniform and regular layer of cells covers the cicatricial scar tissue.

Fig. 11. Photomicrograph. Mag. 415. Autotransplantation of jugular to carotid. Two weeks. Dog No. 201. Surg. Path. No. 2340. Operation, January 14, 1913. Specimen removed January 31, 1913. Walls of the vessels are separated by about one millimetre. The interval is filled in by dense connective tissue. Scar tissue is somewhat irregular but not covered by fibrin except at one point. A uniform and regular layer of cells covers the cicatricial scar tissue.

Experiment No. 11.—Fig. 12. Homotransplantation of femoral vein to jugular vein. Surg. Path. No. 2477. Operation April 11, 1913. Specimen removed April 18, 1913. Shows two valves in transplanted vein, one of which encroaches upon the suture line.

Fig. 13. Photomicrograph. Homotransplantation of femoral vein to the

jugular. Dog No. 346. Surg. Path. No. 2477. Femoral vein transplanted from donor 178. Operation April 11, 1913. Specimen removed April 18, 1913. Complete union between transplant and jugular. Sutures are *in situ*. Accumulation of leucocytes about sutures. Intima smooth and even throughout. No formation of fibrin on intimal surface. Minute amount of connective tissue between apposed ends of vessels.

Case No. 11.—Fig. 14. Arteriovenous anastomosis of femoral vessels. Male adult, age thirty-five. Surg. Path. No. 3550.

Fig. 15. Photomicrograph. Mag. 100. Arteriovenous anastomosis (human vessels). Surg. Path. No. 3550. The artery in close apposition with vein, especially in adventitia and media. Mass of connective tissue which has grown beneath the intima reinforces the junction. In the section at points, the endothelium is intact. A thin layer of fibrin with a few round-cells in it is in the venous portion of the section.

Experiment No. 14.—Homotransplantation of femoral artery to carotid. Dog No. 325 and Dog No. 294. Surg. Path. No. 2753. Shows a nice apposition of vessel ends with a minimum of cicatricial tissue with complete regeneration of intima. Operation March 7, 1913. Specimen removed March 21, 1913.

Experiment No. 30.—Homotransplantation of carotid. Three weeks. Dog No. 223 and Dog. No. 224. Surg. Path. No. 3529. Transplanted portion is undergoing degeneration though the coil of elastic lamina is still present but becoming fragmented. Elastic fibres can be seen in the degenerating portion. Beneath the adventitia of the transplant connective tissue is growing and infiltrating the adventitia. A minimum amount of cicatrix between transplant and original artery. Intima is intact. No functionating blood-vessels present in the transplant.

Experiment No. 50.—Homotransplantation of carotid to carotid. Surg. Path. No. 3526. Intima line of suture shows small dimple. Just beneath the lining cells a suture. Muscularis thrown up into a tent-like fold. In the connective tissue, outside of the muscularis several small deposits of chalk are seen. The adventitial line of suture shows considerable old blood pigment, several small round-cells and fibroblasts. No evidence of real bone formation.

Experiment No. 53.—Homotransplantation of carotid to carotid. Surg. Path. No. 3527. At the intimal side of suture line is thrown up a fibrinous plastic deposit. Muscularis on either side separated by considerable fibrous tissue. Suture line very irregular and shows much more connective tissue production than the others.

Experiment No. 56.—Homotransplantation of carotid to carotid. Surg. Path. No. 3528. Suture line shows usual indentation which is partially filled up by fibrin and blood clot. Just beneath this are seen large irregular masses of calcium. Beneath this the muscularis is apparently continuous. No break in the muscularis or evidence of fibrous union.

There is more or less unanimity of opinion in the manner of restoration of all the coats of the vessel excepting of the intima. Some believe that the surface connective tissue cells become adapted and form the lining endothelium, while the majority believe that the undamaged adjacent endothelial proliferation should cover the exposed connective tissue.

This latter conception is in accordance with the uniformly accepted

interpretation of the repair and regeneration of epithelial defects in the skin and in the mucosæ where epithelium proliferates from the margins and covers the denuded area. It seems to be a question of specificity; of the epithelium it is recognized; of the endothelium, it is questioned.

H. von Schulte after extensive and exhaustive studies on the early stages of vasculogenesis in the cat makes deductions which seem to cast doubt upon the specificity of endothelium. He believes that endothelium may be adapted from connective tissue cells.

The recent studies of W. C. Clarke lend support to his deductions. Clarke holds that the following hypothesis premised in his article is tenable, that is, the surface cells of serous membranes and those lining blood-vessels may regenerate from deep connective tissue cells, and do not necessarily arise from adjacent intact mesothelial or endothelial cells.

Histological studies tend to demonstrate that in the absence of infection, even if the lines of the vessels are not evenly approximated, the chink will be filled in with blood clot. As long as this minute blood clot does not project into the lumen of the vessel there is no accretion and it does no harm. Fibrous connective tissue will grow in and organize the blood clot, and the cells which finally reach the surface will become competent as endothelial cells. In other words, a foreign body in blood-vessels, such as a suture if it is not contaminated, will not produce thrombosis. This may be observed in No. 3729, Fig. 3.

The following conclusions are the result of these studies:

The continuous circular suture with fine silk (vaselined or paraffined) penetrating the media and intima is thoroughly practicable and of ready application.

The circular suture restores the continuity of the vessel without impairing the integrity of its walls or diminishing its lumen.

Side-to-side anastomosis between an artery and a vein can be readily accomplished without the formation of thrombosis.

Fusion of the approximated ends of the vessels takes place by connective-tissue proliferation.

A slight bulging at the suture line does not seem in any way to interfere with the functional efficiency of the vessel, as is shown in two of the specimens.

In the absence of infection, sutures penetrating the intima and entering the lumen of the vessel will do no harm. Connective tissue will grow in and cover the sutures. The cells covering the suture line may become flattened and fuctionate eventually as endothelial cells, or, as many believe, the connective tissue is covered by proliferating endothelium.

In end-to-end anastomosis, by the introduction of one retaining

suture posteriorly, a minimum amount of twisting of the vessels is brought about. This has been found of special importance in the suture of a shorter vessel (splenic and renal).

Autotransplantation and homotransplantation of segments of veins and arteries are perfectly practicable. While a tendency to degeneration of the transplant is indicated, the functional results of the transplant do not seem to be impaired.

In my opinion all transplanted tissue that degenerates sooner or later undergoes connective tissue infiltration, and becomes replaced by the tissue of the host. The transplant acts as a scaffold for the support of the connective tissue of the host.

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EXPERIMENTS OUTLINING THE LIMITATIONS OF OPERATIONS ON THE ABDOMINAL AORTA.

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Plates 23 and 24.

(Received for publication, January 28, 1918.)

From the results of the five experiments presented in this report, there seems to be no difficulty in correcting injuries of the abdominal aorta in dogs, with subsequent perfect restoration of the continuity of the vessel. The complete occlusion of the aorta for a period of 30 minutes is not necessarily followed by serious consequences.[1] For lateral defects in the aorta, or for injuries not involving the entire circumference, a rectangular clamp may be applied for a prolonged period in order that the circulation should not be completely cut off. An operative field free from blood can thus be obtained while the circulation is maintained through the remaining lumen of the aorta.

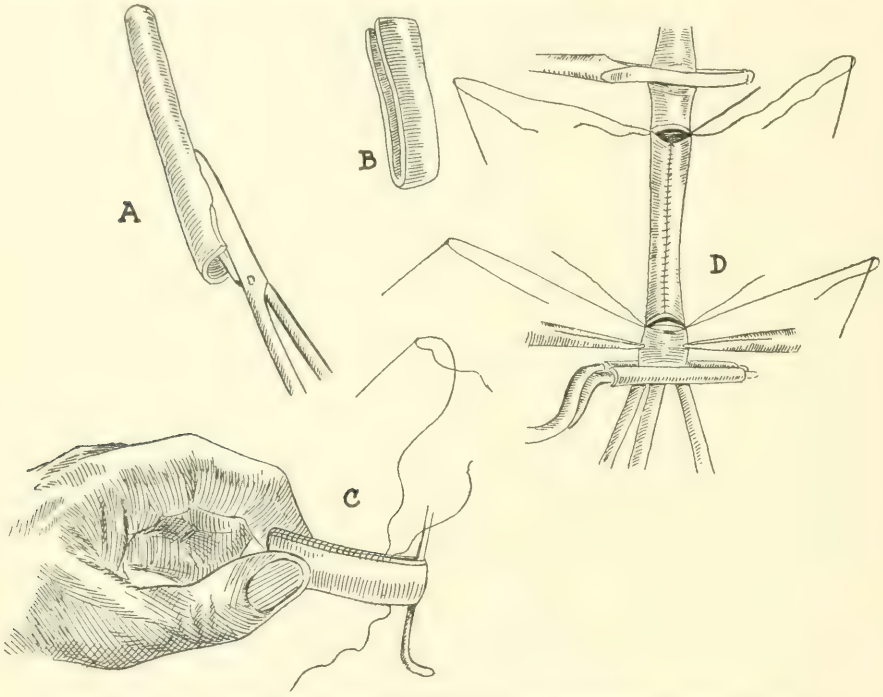
In the instances in which a portion of the aorta must be resected, an arterial segment taken from another animal can be safely utilized as a transplant. Smaller vessels can be adapted to the caliber of the aorta by the following procedure which was devised by Jeger and Helmuth Josef[2] (Text-fig. 1). The artery is split longitudinally (*A*), the ribbon thus formed is then folded double (*B*), and both edges are closed with a continuous suture of very fine silk (*C*). In this way, a tube, double the original size of the vessel is made, which is then transplanted end to end between the resected ends of the aorta (*D*).

Further experiments were undertaken to determine the practicability of reestablishing the continuity of the severed aorta by the cir-

[1] All operations were performed under complete ether anesthesia.

[2] Jeger, E., Die Chirurgie der Blutgefässe und des Herzens, Berlin, 1913.

cular suture. The results obtained seem to indicate that while the operation is possible, the difficulty of approximating the severed ends during the suture is greatly increased, on account of the retraction of the aortic tube. The approximation entails such injury that the probability of thrombosis is much increased. Therefore, when the aorta is completely severed, the introduction of a transplanted segment would be indicated and the procedure would be the same as when a portion of the aorta had been removed.



TEXT-FIG. 1. Method for transplanting an arterial segment to the aorta. *A*, first stage of the operation, *B*, second stage, *C*, third stage, and *D*, fourth stage.

Danis,[3] in an exhaustive study, showed that the ligature of the abdominal aorta in human beings has hitherto always resulted fatally. Braun[4] has reported a successful suture of the abdominal aorta on a 6½ year old girl with a ganglioneuroma about 4 pounds in weight.

[3] Danis, R., Anastomoses et ligatures vasculaires, Brussels, 1912.

[4] Braun, cited by Jeger,[2] p. 236.

EXPERIMENTS.

Suture of a Longitudinal Incision in the Aorta.

Dog 1.—March 29, 1916. The aorta was exposed below the renal vessels by a median laparotomy. An incision 2 cm. in length was made through all the coats of the right anterolateral wall of the aorta. A rectangular clamp was applied to the aorta in order to shut off the blood from the operative field without completely occluding the aortic circulation. The incision was then closed with a continuous suture of silk. The parietal peritoneum was sutured over the aorta, and the laparotomy wound was closed by suture in layers.

Autopsy.—The dog was killed June 5, with chloroform. There were no evidences of infection. The abdominal wound healed by primary intention. The peritoneum was free from adhesions. The peritoneum covering the aorta was perfectly smooth, and showed no signs of a recent operation.

Gross Examination.—A cross-section of the suture line shows that the vessel is not surrounded by adventitious tissue except at the site of the suture. At this point the vessel wall is but slightly thickened. The intima is relatively smooth except along the suture line. Here there are slight, flat elevations of coagulated blood. These coagulations are old; their surfaces are smooth and they project into the lumen but slightly. New accretions of coagulated blood are apparently taking place at the site of the old blood coagulations described above.

Microscopic Examination.—Section of the vessel wall shows that the structure is intact and the wall preserved. The intima is smooth at the point of this section and shows no plaques of fibrin.

Suture of a Lateral Defect in the Aorta.

Dog 2.—Small female; bulldog type. April 5, 1916. The aorta was exposed through a median laparotomy wound. An elliptical segment of the aorta was excised, and the resulting defect was closed by a continuous longitudinal suture. Although the lumen of the aorta was diminished about one-third of its diameter, the general health of the animal did not seem to be impaired.

Autopsy.—The dog was killed with chloroform April 12. The specimen showed no evidence of thrombosis.

Gross Examination.—At the point of suture the vessel is surrounded by adventitious tissue about 4 cm. thick. The lumen which is present is but slightly if at all diminished in size. The intima is relatively smooth except just at the suture line where it is finely roughened by what appear to be minute plaques of fibrin.

Microscopic Examination.—The section immediately adjacent to the site of suture shows a considerable infiltration of the adventitious tissue by round cells. The structure of the vessel wall is well preserved. At points there is the suggestion of fibrin formation on the intima. In the lumen of a large sized branch of

the aorta at this point is an extensive thrombus. In the many small vessels in the tissue immediately adjacent, the blood circulation has apparently been free.

Homotransplantation of Carotid Tube to Severed Aorta.

Dog 3, Donor.—April 18, 1916. Both carotids were removed. The carotids were slit longitudinally, and the free lateral borders sutured together so as to form an arterial tube twice the caliber of a single carotid. The dog was killed under ether at the operation.

Dog 4, Host.—Small female fox-terrier. A segment of carotid tube 3 cm. long was transplanted by a biterminal suture between the severed ends of the abdominal aorta. The transplantation was made somewhat difficult by inability to control completely the hemorrhage from the aorta during the suture. The immediate circulation, when the operation was completed, was satisfactory. April 20. Animal died.

Autopsy.—No evidences of leakage. Lumen patent. Sutures plainly visible. The specimen showed evidences of lateral thrombosis.

Gross Examination.—The vessel wall is intact but slightly thinner than the normal vessel adjacent. The longitudinal suture lines which have reconstructed the segments of the carotid into the single tube for transplant are plainly visible, though apparently covered by tissue. The intimal surface of the transplant is but slightly roughened by plaques of fibrin. The transverse suture lines are slightly roughened by minute coagula.

Microscopic Examination.—Section across the transverse suture line shows that the intimal surface is covered here and there by a thin layer of coagulated blood. The transplanted segment is somewhat degenerated and infiltrated by round cells. Section through the center of the transplanted segment shows a thin layer of coagulated blood on the intima, and the vessel wall has partially degenerated though it is physically intact (Fig. 1).

Homotransplantation of a Segment of Aorta to the Aorta.

Dog 5.—Medium sized male mongrel. May 17, 1916. The aorta was exposed by a median laparotomy and liberated for a distance of about 5 cm. Two elastic clamps were then applied and the aorta was severed. A segment about 3 cm. long had been removed about an hour before from a small mongrel dog that had been killed by chloroform. This segment was now interposed between the severed ends of the aorta and united by a biterminal suture. After the circular suture was completed, there was no leakage.

Autopsy.—The dog was killed with chloroform June 5. With the exception of the adhesion of the omentum to one point in the line of suture there were no traces of peritoneal irritation. The peritoneum covering the aorta was absolutely smooth. There was some thickening about the transplanted segment. No thrombosis.

Gross Examination.—The aorta is surrounded by a mass of adventitious tissue measuring about 1 cm. in thickness. At the site of the suture a distinct wall of the vessel is apparent, differentiated from the surrounding tissue. The lumen which is present is somewhat diminished in size at the site of repair. There are no blood coagulations in the lumen. The intima appears relatively smooth.

Microscopic Examination.—There is extensive round cell infiltration of the adventitia in and about the sutures. External to the vessel wall are areas of hemorrhage—the result of operation. The vessel wall at this point is intact and whatever intima is shown in the section is free from blood coagulations.

Transplantation of Fascia to a Lateral Defect in the Aorta.

Dog 6.—Medium sized fox-terrier. May 24, 1916. By a median laparotomy the aorta was exposed and liberated for a distance of about 5 cm. A rectangular clamp was applied, and a section ½ cm. square was removed from the anterior wall. This defect was covered by transplanting a piece of aponeurosis taken from the abdominal wall.

Autopsy.—The dog was killed on June 9 with chloroform. The peritoneal cavity was free from adhesions except for a fibrous deposit about the parietal peritoneum corresponding to the field of operation. There were no evidences of leakage from the aorta, and there was no obstruction or thrombosis. The area of intimal surface corresponding to the transplant was perfectly smooth.

Gross Examination.—The specimen consists of a segment of aorta surrounded at the site of fascial transplant by a mass of adventitious tissue. Cross-section shows that the arterial wall at the transplant is deficient and is replaced by scar tissue. The intimal surface over the site of the transplant is covered with a thin layer of fibrin. This surface is relatively smooth. The vessel lumen is in no way diminished at this point. Adjacent to the patch projecting into the lumen is a rounded mass of coagulum about 1 mm. long, apparently a suture end free in the blood stream covered by this blood clot.

Microscopic Examination.—Between the ends of the sutured artery there is a mass of loosely built connective tissue. The surface is smooth where this granulation tissue is exposed to the blood stream. An intact cellular layer of adapted connective tissue cells forms this smooth surface. There is a small island of fibrin attached at one point. In the depths of the artery wall are sections of several sutures. Around the sutures are cellular aggregations among which are many polymorphonuclear leukocytes. At one point in the tissue, held in the interval between the artery ends, there is a deposit of lime salts suggesting the early stages of ossification. This sutured vessel demonstrates a favorable repair with a satisfactory reestablishment of the blood circulation (Fig. 2).

CONCLUSIONS.

1. Injuries of the abdominal aorta in dogs may be corrected with subsequent perfect restoration of the continuity of the vessel.

2. The complete occlusion of the aorta for a period of 30 minutes is not necessarily followed by serious consequences.

3. In cases in which a portion of the aorta must be resected, an arterial segment taken from another animal can be safely utilized as a transplant.

4. While the reestablishment of the continuity of the severed aorta by the circular suture is possible, the approximation of the severed ends during the suture entails such injury that thrombosis frequently occurs. Therefore, when the aorta is completely severed, the introduction of a transplanted segment is indicated.

5. An arterial tube of increased caliber made of smaller vessels such as the carotid lends itself readily as a transplant to the severed aorta, with a reasonable assurance of reestablishing the continuity of this vessel.

6. Defects in the aorta can be readily corrected by the use of fascial transplants with a minimum danger of thrombosis.

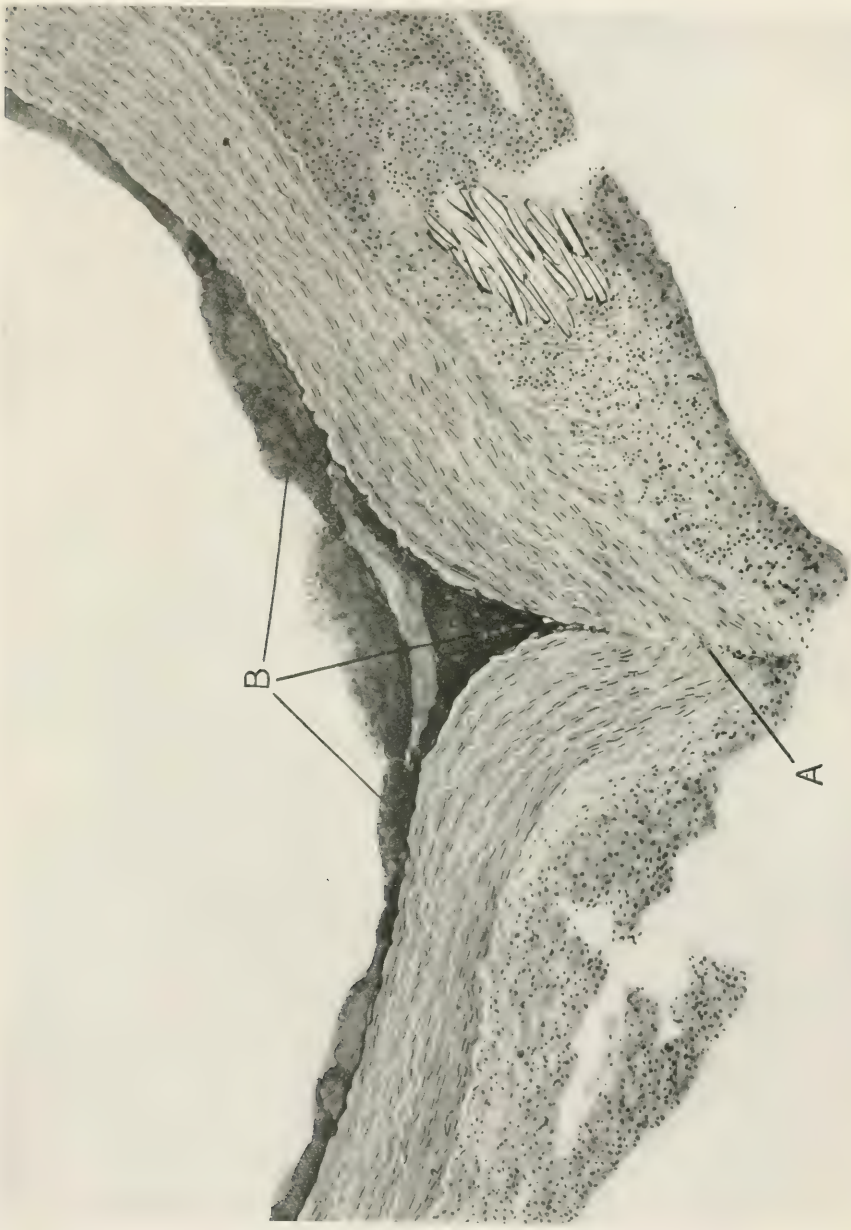
EXPLANATION OF PLATES.

Plate 23.

Fig. 1. Sutured vessel wall. *A*, suture line of vessel wall. Eversion of the coats of the vessel wall in order to bring the intima in contact with the intima at the suture line. There is a parietal coagulation of blood, *B*, into which reparative tissue grows in the final establishment of repair. Compare with Fig. 2, in which growth of tissue is complete, reestablishing the intimal lining of the vessel.

Plate 24.

Fig. 2. Sutured vessel wall. The everted vessel wall, *A*, joins the tissue transplant, *B*. The interval between the vessel wall and tissue transplant is covered by a mass of reparative tissue, *C*, which has grown into a blood coagulum, usually found present in early specimens after vascular suture. Compare with Fig. 1.



(Goodman: Operations on the abdominal aorta.)

FIG. 2.

(Goodman: Operations on the abdominal aorta.)

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REPORT OF A CASE OF CYST OF THE TESTICLE IN A DOG

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The first description of cysts of the testicle is that of Astley Cooper (1) in 1845, under the name of hydatid disease of the testis. He described four cases, and sharply divided them from cysts arising in connection with new growths, which he termed fungoid disease of the testis. There does not seem to be evidence that they were of neoplastic origin, although such an opinion has been recently vouchsafed for them (13). Succeeding accounts were less accurate in differentiating cysts of the testicle from cystic neoplasms. Cases were, however, described by Curling (2), 1850, Hockenburg (3), 1885, and Walliman, (4), 1911. Albert (5) mentions three cysts of the testicle in 6,000 autopsies.

The present case is that of a shepherd dog, nine years old.

Past History: Dog was run over by an automobile when four or five years old.

Present History: Swelling of scrotum was noticed one and one half years ago. Increase in size was gradual. Dog was healthy save for occasional attacks of obstipation lasting three to five days, during which time he gave evidence of being severely prostrated. He had just recovered from such an attack three weeks ago, but was at this time in apparent good health.

Examination: Scrotum was much swollen, spherical, smooth, and fluctuated; it did not transmit light. It could not be reduced into abdomen. One testicle could be made out at the lower extremity of scrotum. No signs of inflammation were present.

Diagnosis: Hernia and hydrocele.

Operation: On incising tunica vaginalis, a smooth rounded cyst was seen. Operation for orchidectomy was done, and cyst and portion of vas removed. At end of operation, a single testicle could be plainly felt in the scrotum. The dog recovered from operation, the wound healed, and he is now in good condition, four months after operation.

Gross Pathology: Surg. Path. No. 5264. Specimen consists of a spherical body, the diameters of which are 7×6.5 cm., Fig. 1. In the fresh state, it showed a smooth, glistening surface, fluctuated, and transilluminated light. The surface shows many large injected veins. At a point on one lateral sur-

face there is a bluish, slightly raised area, 3 × 3 cm., which is firm on pressure. On the opposite surface is seen a longitudinal mass, 6 cm. long, 0.6 cm. in width at its central part, and 1.3 cm. at either end. This is clearly the epididymis, and head, tail and body are shown attached to cyst wall. From the tail of the epididymis, the vas is seen to arise and extend upward. Section through the vas shows it to be patent. On opening the cyst, Fig. 2, the surface is seen to be glistening and for the most part smooth. At points there are slight ridges or shelves that project from the wall. From these ridges and also from points on the wall that are relatively smooth, there extend coarse strands that pass to the cyst wall opposite. These form a rough, scanty meshwork in which are deposited small, soft, yellowish masses that vary in size, the largest being about 3 mm. in diameter. There is a thin membrane stretching between some of the strands. Section through the circular bluish mass referred to above shows it to be 8 mm. in thickness at its central part; and from that point it diminishes until it ends in the cyst wall, the thickness of which is 1 mm. At the periphery of the mass, the cut surface is smooth, homogeneous and dark in

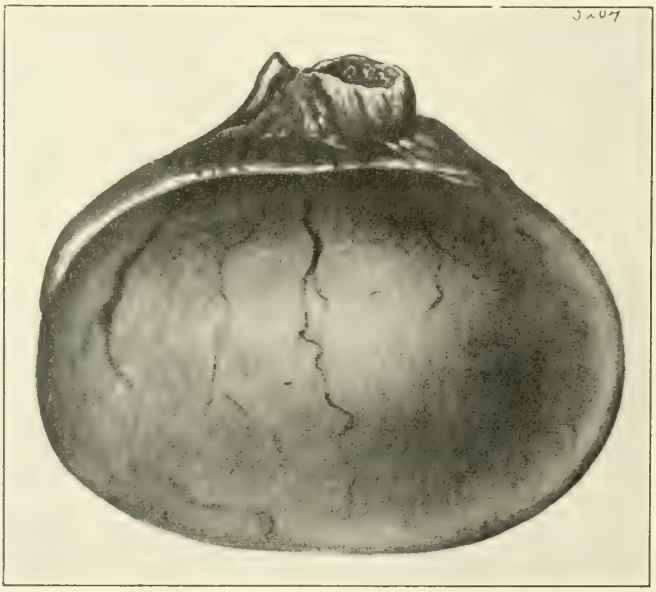


FIG. 1. Surface form of cyst of testicle. Epididymis attached to posterior portion of cyst capsule. Injected veins are seen on the surface. Diameter of cyst, 7 × 6.5 cm.

color. Centrally, it shows several large irregular cystic spaces, is of a lighter color and does not give the compressed appearance of the peripheral portion. The mass is the apparent remains of the testis. It is notable that the intra-

cystic network is in greater abundance near, and has a more direct connection to, this testicular mass than to any other part of the cyst wall. A few strands reach over to the cyst wall connected to the epididymis. The disposition of these various strands is very suggestive of the fibrous septa that project from the mediastinum to the tunica albuginea. A portion of the peritoneal sac which extended through the inguinal ring is present, attached to the tail of the epididymis and the cyst wall. The sac was closed off, and presented no communication with tunica vaginalis. The serous parietal layer of the tunica vaginalis was continued over the cyst forming the visceral layer of the tunica vaginalis. There was no protoplasmic connection between the epididymis and the testicular mass. The fluid in the cyst was unfortunately not examined.

Microscopic Pathology: Figure 3 represents the circular bluish mass referred to as the remains of the testis. The external covering is of fibrous connective tissue. Considerable hyaline degeneration has taken place throughout the capsule, interrupting the fibers and destroying their parallel arrangement in various places. Beneath the capsule is the parenchyma. This is irregularly divided up by cysts of varying sizes and shapes, many of which are visible with the naked eye. The cysts are lined for the most part by a single layer of elongated flattened cells. Many, however, are lined by cuboidal cells. The majority of the cysts are empty; some contain a homogeneous pink-staining substance, apparently serum; still others contain red blood cells. The cells of the parenchyma are very unusual. They are of two varieties. The more prominent type consists of cords or strands of polygonal epithelial cells with vesicular nuclei. Near the capsule, they tend to be arranged parallel to the surface. More deeply, the arrangement is completely broken up by the cysts. In favorable fields the width of these cords is seen to be made up of two cells. In other fields, the cords do so merge into each other, and are so overlapped by other cells, that such a division is impossible. Where it can be seen, the impression is definitely given of tubules in which the lumina have collapsed, and the lining cells are in opposition. There is a delicate connective tissue framework separating these cords. In places this is apparently absent, the cells resting back to back against each other.

The second type of cell is found in the connective tissue spaces between the cords, and overlapping the cords themselves. It is a rounded, mononuclear cell. The smaller ones have much chromatin and resemble lymphoid cells. The larger ones have abundant cytoplasm, vesicular nuclei, some of them contain brown granules resembling hemosiderin. They have the general form of large mononuclear phagocytes. These cells, especially the small mononuclears, tend to be arranged in groups, although they are seen separately throughout. In this slide, they are numerically few, but in Fig. 4 they are much more common.

Hemosiderin in addition to being contained in the cells can be seen free in the connective tissue spaces. The lining of the cyst is composed of elongated flattened cells. In many places this is destroyed, the epithelial strands projecting into the cyst cavity uncovered.

The tissue is quite vascular, capillaries and larger blood spaces being especially prominent.

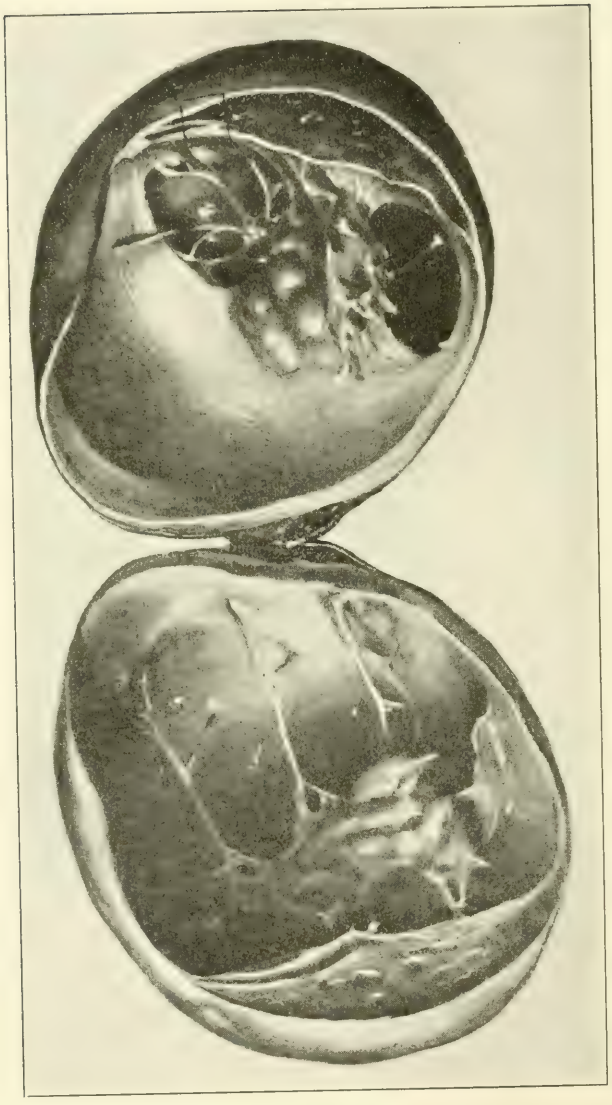


FIG. 2. Interior of cyst. Small cystic spaces are seen in cross-section of remains of testis. Fibrous strands bridge the cavity of the cyst. Thickness of capsule, 1 mm. Thickness of testis, 8 mm. at its widest part.

No functionating or hypertrophied tubules are present. Spermatozoa and the forerunners of the sex cells are nowhere to be seen.

Section (not reproduced). This section was made through a portion of the cyst wall between epididymis and testicle proper. It shows the capsule, and, lining of the inner surface of either extremity, a small mass of testicular tissue resembling that described above. The cords of polygonal epithelial cells here have a more irregular arrangement, giving the impression of being bent on each other. In some places a double layer of cuboidal cells surrounds an epithelial cord, so that it appears as if one cord of cells were being invaginated by another.

The mononuclear cells described above are more frequent here. There are little collections of small round cells and many isolated large mononuclear cells. The latter frequently contain hemosiderin. Here hemosiderin is also present free in the connective tissue spaces.

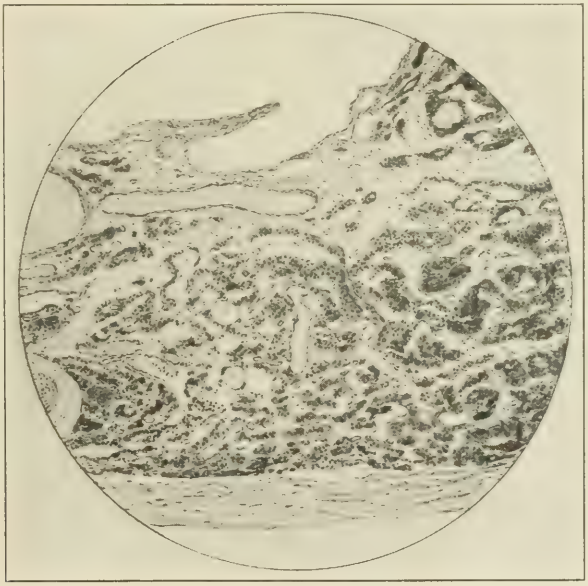


FIG. 3. Low power of testicular mass. Irregular cords of polygonal epithelial cells broken up by cysts. Some of the cysts contain red blood cells. There are many capillaries and wide sinuses in the section. Above is the lining of the cyst, composed of elongated flattened (mesothelial) cells; below is the fibrous capsule.

The blood vessels likewise partake of the irregularity in this section, being more tortuous and more irregularly disposed.

Figure 4. This section was taken through the epididymis, and included

some subjacent testicular tissue. The epididymis reveals no abnormality. The head shows the usual stratified lining epithelium, the surface cells of which are long, narrow, columnar cells, and possessed of cilia. The muscular coats are well preserved. Separated from the epididymis by a dense band of fibrous connective tissue is a small amount of testicular tissue differing completely from that previously seen. Seminiferous tubules are present in varying degrees of function. For the most part they have wide lumina. Frequently these are filled with degenerated and cast off sex cells. Some of the tubules are apparently functionating. They present an outer layer of one to three rows of flattened connective tissue cells. Upon this rests the lining epithelium of spermatogenic cells, first small cuboidal cells with deeply staining nuclei, then several rows of large spherical cells with vesicular nuclei in varying stages of mitoses. Bordering on the lumen are small round cells, a few rod-shaped cells and a very few almost mature spermatozoa. This typical arrangement is only infrequently seen, most of the tubules showing marked disturbance of function. A few have collapsed. Many, however, show dilated lumina and have their epithelium narrowed down to one or two layers of flattened or low cuboidal cells.

In considering the pathogenesis of cysts of the testicle, it is simpler to classify first their modes of origin as either retention cysts or non-retention cysts. Retention cysts may conceivably arise through a blocking of certain portions of the excretory apparatus of the testis, as vas deferens, ducts of the epididymis or seminiferous tubules. Or they arise from some glandular remains, cut off in the process of development, which suddenly receive the stimulus to secrete, as the cysts of the parodidymis. In these cases there is a closed cavity or duct lined by a secreting epithelium. The secretion of this glandular epithelium tends to flatten the lining cells and by gradual distention to compress the adjacent connective tissue so that a capsule composed of epithelium internally, and connective tissue externally, is formed. The cyst contents are derived from the secreting epithelium. Similarly, cysts derived from the blocking of lymphatic channels might be conceived, as hygromata, with the lining here of endothelial origin.

Non-retention cysts may be said to arise in the testicle in connection with one of the following processes: (1) Hemorrhage, (2) necrosis, (3) extravasation of seminal fluid, (4) neoplastic origin. It is the cyst arising as a result of hemorrhage or necrosis

that is to be especially considered. (The extravasation of seminal fluid through rupture of tubules can be considered of like nature.)

In the formation of hemorrhagic and necrotic cysts a classical description, that of Adami and Nichols (6), is somewhat as follows: Blood is exuded, and a destruction of inclosed tissue results. Through autolysis and leukocytic agencies, the bodies of the corpuscles, cell débris, and finally the hemoglobin, are absorbed, leaving a clear serous fluid around which a capsule has gradually formed. Descriptions of this character, however, leave much to be desired.

Why is not the hemorrhagic area organized, what causes the formation of an internal lining of flattened epithelial or mesothelial cells, how is the peripheral portion of the capsule, composed of compressed fibrous tissue, to be accounted for, what is the cause of the persistent distention and enlargement of the cyst sac, its swift refilling when emptied? These are some of the questions that lack adequate explanation in the non-retention cysts. William C. Clarke has advanced a hypothesis that meets these questions. He supposes that where cysts are formed as a result of hemorrhage, there are substances present which act in a two-fold manner. (1) They keep the blood fluid, and (2) they raise the osmotic pressure in these cavities. These substances may be of salt nature, varying with each man's individual blood chemistry. This hypothesis explains why connective tissue cells do not organize the hemorrhage, since it has been shown *in vitro* that fibroblasts do not grow into fluid but that they spread themselves about it and form a covering. This has been demonstrated in Dr. Clarke's laboratory by the formation of experimental mesothelium (7). Specially prepared collodion foreign bodies were introduced into the subcutaneous tissue of a dog. Specimens were removed after 20 to 30 days, and the collodion bodies were found covered by elongated flattened cells closely disposed and parallel to the free surfaces. Further experiments *in vitro* showed that cells surrounding serum became elongated and flattened in a similar way. Through the observation incubator it was seen that these cells were derived from connective tissue cells. It was

also shown that where open collodion boxes containing serum were placed in the tissues, the serum was not invaded but was always covered by a flattened layer of connective tissue cells. Thus it was demonstrated that connective tissue surrounding a relatively non-irritating foreign body as collodion or serum, would form a lining pavement mesothelium composed of elongated flattened cells. In these cases, no capsule was formed, no fluid distending the cavity occurred, and a cyst could not be said to have been produced. It was stated above that the substances that kept the blood fluid also raised the osmotic pressure within the cavity. With higher osmotic pressures obtaining, the fluid elements of the blood and lymph diffuse into the space and cause increasing distention. The bordering connective tissue cells become flattened to form a mesothelial lining, as explained above, and, in addition, the distending pressure is transmitted peripherally, causing compression of the adjacent connective tissue and ultimately its fibrous capsule. The increasing contents of the gland and the formation of the capsule can thus be explained in these non-retention cysts. In retention cysts, the secretion of the lining cells is held to be the factor that distends the cavity and causes mechanical flattening pressure on the lining cells. It is this same secretion that causes the cyst to fill up again when its contents have been evacuated. In non-secretory cysts this mechanism is absent, and the hypothesis of Clarke is adequate to explain these above-named phenomena. Mere fluidification of hemorrhagic and necrotic contents would presumably not cause progressive flattening pressure, progressive distension, and reaccumulation of fluid. The supposition might be offered that the connective tissue cells in the presence of fluid take on by metaplasia a secretory activity, but this finds no convincing analogy in cellular pathology elsewhere.

An interesting corollary to the hypothesis of Clarke is found in recent work on fibrinolysis. In brief, it was observed by Goodpasture (8), that a clot formed from the blood of people who had cirrhosis of the liver autolyzed in 3 to 12 hours, leaving clear serum. If blood is drawn from a relatively normal individual

into a sterile flask, it will remain clotted a week or longer, thereafter slowly dissolving. In certain people, especially in those suffering from cirrhosis, and in dogs injected with proteoses or poisoned by phosphorus, a clot forms, but the fibrin autolyzes, leaving, in three to four hours, the fluid serum. So that in these conditions, hemorrhage occurring in the tissues, instead of clotting, forming a fibrin meshwork and then organizing, undergoes fluidification. In fact, in one of the cases reported by him, autopsy immediately after death showed a fluid pond the size of an egg in the subcutaneous tissue of the abdominal wall. No evidence of clot was present. What would have happened to this collection of serum in a confined space is difficult to tell. In the light of the experiments in the observation incubator above mentioned, it does not seem too much to say that a lining membrane of flattened mesothelial cells would have formed about it. Thus we would have an abnormal collection of fluid, surrounded and localized by a pavement lining derived from connective tissue. Whether this pond of blood would have in addition acquired a fibrous capsule and show a tendency to increase in size can be matters for speculation only.

However, the mechanism of fibrinolysis, or fibrin solution, also possesses interest in line with the hypothesis which has been discussed. It is known that fibrin dissolves in dilute solutions of certain salts as NH_4, SO_4, KNO_3, Na_2, SO_4, NaCl (9). That the lysis of fibrin in the tissues is dependent on the action or presence of salts has not been shown. Conceivably, however, the dissolution of fibrin may be due to salts acting alone, to enzyme action plus the presence of salts acting as a catalyzer, or to enzymes alone. It has been reasonably proved that whatever is the acting substance, it is contained in the leukocyte (10). The aggregation of leukocytes is needed for the solution of the fibrin. The opinion of Dastre (10, 11), who first called attention to fibrinolysis, is that salts are the important substances. If this latter statement is verified, it may be said that salts present in sufficient quantity to cause solution of the fibrin, may raise the osmotic pressure of the cavity in which they are contained. Conditions

are then favorable for a diffusion of liquid into a region of higher osmotic tension. In this way increasing distention and pressure by the fluid would accomplish the remainder of cyst production. The supposition of the presence of salts is considered because of its suggestive value. That salts are present in increased quantity in these cavities has not been shown nor, as far as I know, attempted. It is thought by Goodpasture that enzymatic action is the basis of fibrinolysis.

There is then the theory that salts may be present in hemorrhagic cavities acting both as catalyzers to fibrinolytic enzymes and as osmotic tensors. The quantitative and qualitative variations in these salts would depend on the individual, so that a determining factor in the development of cysts following extravasation of blood would lie in the tissue and blood chemistry of the individual, just as now it is known that certain clinical conditions which have a definite chemical basis, determine whether blood will clot and organize, or liquefy.

A few cysts of the testicle following trauma and hemorrhage have been described, but in all except one neoplasm developed. In this one the description is hardly adequate (14).

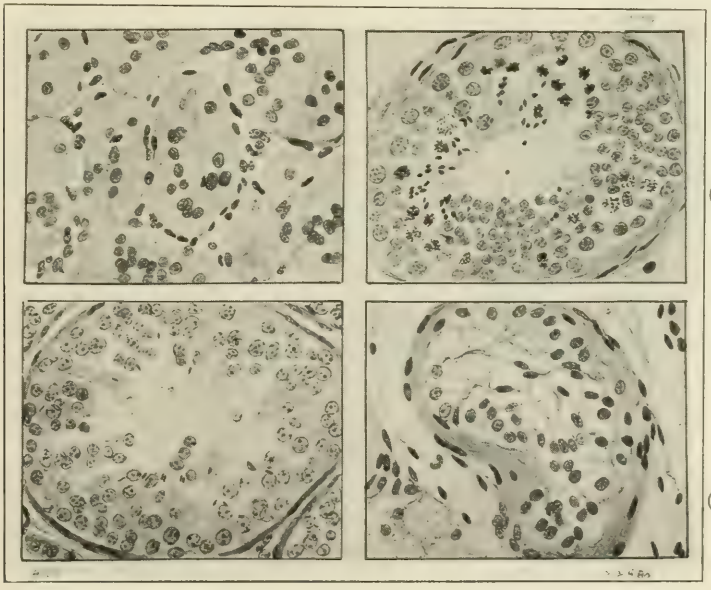
Hemorrhagic and degeneration cysts are said to occur in the brain following anemic infarction, in old gummata or abscesses in the tissues, in corpora lutea, in the bone marrow of old age, in the thyroid, pancreas, kidneys, and spleen (12).

Cysts arising in connection with neoplasms may find their origin in hemorrhage or necrosis, or in the secretion of abnormally enclosed glandular epithelium. Cystic neoplasms of the testis have been recently claimed to be of teratomatous nature (13), in which case their origin is probably from the embryonal development of the sexual blastomeric cell, as other structures of teratoma are developed. Here, too, however, the development of blood cysts is possible, for, in fact, the majority of the cysts described by Ewing in his series of teratomata showed the presence of bloody fluid (13).

The cyst here reported is considered a non-neoplastic, non-

retention cyst of the testis having its origin in hemorrhage or degeneration, with trauma as a possible etiological factor.

There is no evidence that this is a neoplasm. The essential cells, though unusual, show a certain uniformity in size, shape, and arrangement, which is not expected in a tumor. This arrangement, as was described, is frequently broken up by cysts, but evidence of its basic similarity is to be found in the different sections. Mitotic figures, apart from the area of spermatogenic cells, are nowhere seen. Further, the essential cells do not arise in the rete testis, as tumors of the testis have been shown to do since Curling (2) first pointed it out. These cords of epithelial cells rather present the picture of atrophic tubules with collapsed lumina. Comparison with a cryptorchid testicle of a man, 22 years old, demonstrates a certain similarity. The cells, though



Section 4. High power. (1) Testicular mass. Polygonal cells arranged in cords two cells wide giving the appearance of atrophic tubules with collapsed lumina. Smaller groups of mononuclear cells present in connective tissue framework. (2) Relatively normal tubule of a dog's testicle. (3) Relatively normal tubule from a human testicle. (4) Tubules of a cryptorchid adult human testicle, showing tendency toward obliteration of lumen.

differing from those in the present case, tend to be opposed to one another, in some places completely obscuring the lumen. The testicle of a seven-months' human fetus shows also a lack of lumen in the seminiferous tubules. In all these cases, including the one under consideration, the lack of active function may account for the absence of lumina, and the consequent apposition of adjacent cells.

The cyst does not give evidence of being a retention cyst. The vas is patent, the epididymis is not affected. Further proof of its being a cyst of the testis proper is the arrangement of the fibrous strands in the cyst cavity quite apart from the epididymis, and also the disposition of the atrophied tubules lining the inner surface of the capsule. The epididymis is healthy and undisturbed. Blocking of the seminiferous tubules does not seem to have taken place. Except for the small area of partially functionating seminiferous tubules, there are no patent tubules, no wide dilatations and enlargements, and no evidence of spermatozoa. The persistence of some testicular tissue beneath the epididymis may be ascribed to the protecting influence that the margins of the epididymis had. That this is not of tubular origin, and, as such, a spermatocele, cannot be rigorously denied, but it seems unlikely. The fact that cysts occur only in the area of atrophic cells, or the epithelial cords, and none in the partially functionating tissue, is strong evidence that the cysts did not originate there. Had that been so, some of the smaller cysts would probably have been found alongside dilated tubules.

The multiplicity of the cysts suggests a degeneration phenomenon as in the cystic degenerations of the ovary. This could of course occur just as easily with numerous areas of hemorrhage. Further, the presence of hemosiderin free in the connective tissue spaces, and inclosed in the large mononuclear cells suggests that it is of hemorrhagic origin. The history of severe trauma can be added. So that by exclusion and *prima facie* evidence, this cyst can be considered probably of hemorrhagic origin, or of hemorrhagic and degenerative origin. The old age of the dog suggests that degeneration played a part.

CONCLUSIONS

1. The explanation of the mechanism of a retention cyst is adequate within the limits of our present knowledge. The damming back of secretions in an epithelial lined cavity closed off in post-natal life or congenitally accounts for the accumulation of cyst contents and the formation of a cyst capsule.

2. The pathogenesis of non-retention cysts has not been adequately explained. The supposition has been made by William C. Clarke that there are in hemorrhagic and necrotic cavities substances which raise the osmotic pressure and induce filling of the cavity and capsule formation. These substances may be of salt nature and perform the two-fold mechanism of keeping a fluid medium and acting as osmotic tensors.

3. The phenomenon of fibrinolysis affords an interesting corollary to this hypothesis. Through its agency hemorrhage may take the form of an unclotted fluid pond. Further, the mechanism of fibrinolysis may prove to be dependent in part on salts present in the tissues.

4. The case reported is considered a non-neoplastic, non-retention cyst of the testis. Its pathogenesis is considered as arising from hemorrhage or degeneration, or from both. Trauma is a possible etiological factor.

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Tetany in a Case of Sprue

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TETANY IN A CASE OF SPRUE*

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Early in 1919, Bassett-Smith[1] reported a case of sprue in which tetany developed shortly before the death of the patient. The author stated that his was the first published account of this complication of the disease. As no similar reports have been found in the literature since that time, it was considered that this case might be of interest both on account of its rarity and because of certain significant features bearing on the question of the etiology of tetany.

REPORT OF CASE

History.—R. W. C., an American medical missionary, aged 41, entered the private ward of the Presbyterian Hospital, Sept. 20, 1919, complaining of abdominal pain and diarrhea. As in all previous visits, he was cared for by Dr. David Bovaird. The patient had had measles and scarlet fever as a child; dengue in 1909, and bacillary dysentery in 1912. Since 1907, when the patient arrived in the Philippine Islands, small ulcers had been continuously present in his mouth, and he had been bothered by diarrhea of a greater or less degree. In 1914, his condition became very much aggravated. The tongue became red, swollen and tender, and the small white ulcers along its margin merged. Moderate abdominal tenderness with slight distention accompanied a troublesome diarrhea. The stools were large, white, semifluid and frothy, with an offensive odor. He suffered from hemorrhoids, and fissures appeared in the margin of the anus. In the six months preceding his first entrance to the Presbyterian Hospital, the patient lost 40 pounds.

First Admission.—The patient was admitted, July 24, 1914, and discharged, Aug. 17, 1914. The lips were cyanotic; there were white spots on the tongue; on the buccal mucous

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1. Bassett-Smith, P. W.: Lancet **1**: 178 (Feb. 1) 1919.

membrane were two shallow ulcerations with a narrow zone of inflammation around them. There was a systolic murmur at the apex and the base; the abdomen was tender and tympanitic. The systolic blood pressure was 114; the diastolic, 70. Blood examination revealed: hemoglobin, 88 per cent.; red blood cells, 4,800,000; white blood cells, 9,200; polymorphonuclears, 56 per cent.; lymphocytes, 39 per cent.; eosinophils, 5 per cent. The stool contained no ova or parasites; the Cammidge test was positive; amylase was diminished. The diagnosis was "sprue." Under a regulated dietary regimen of fruit and proteins, the patient improved considerably, and on leaving the hospital went to live in New Jersey, where he seemed to be on the road to recovery. Exercise, however, brought on renewed attacks, and the patient was forced to reenter the hospital in 1916.

Second Admission.—The patient was admitted, March 31, 1916, and discharged, Aug. 5, 1916. He presented about the same symptoms as on his previous admission, with the addition of anemia. Blood examination revealed: hemoglobin, 68 per cent.; red blood cells, 3,600,000; white blood cells, 9,200; polymorphonuclears, 71 per cent.; lymphocytes, 28 per cent.; eosinophils, 1 per cent.; blood Widal test, negative; blood culture, negative. Throat culture revealed no Klebs-Loeffler bacilli. The Wassermann test was negative. The stool was light and frothy; it contained no ova, parasites, blood or pus; trypsin and amylopsin were markedly diminished; starch granules, striated muscle fibers and fatty acid crystals were seen. Total fat was 39.0; neutral fat, 14.09; fatty acids, 24.91; 60 per cent. or more of the organisms noted were gram positive. A serial test meal was given. The gastric contents after one-half hour showed: free hydrochloric acid, 38; total acid, 62; after one hour: free hydrochloric acid, 41; total acid, 58. A roentgenogram of the stomach revealed a small amount of residue five hours after eating. The diagnosis was "sprue." The patient had occasional attacks of nausea and vomiting. Improvement began with a low fat diet, composed mostly of fruits and lime-water, and continued up to the time he left the hospital.

Third Admission.—The patient returned to the Philippines in October, 1917, where he seemed to do well until January, 1919; at this time his trouble returned with renewed force. He had from two to four light, frothy stools a day, and for the first time was troubled with pain in the upper part of the esophagus. In the late summer, he returned to the United States and reentered the Presbyterian Hospital. He was weak, emaciated and anemic, and his speech was feeble. The tongue was red and raw, with numerous ulcerations, and the buccal mucous membrane was marked by erosions. A faint blow was audible over the mitral ring. Liver dulness was diminished. The abdomen was distended and ten-

der, but there was no mass or rigidity. The spleen was not palpable. The testes were tender.

September 21, blood examination revealed: hemoglobin, 65 per cent.; red blood cells, 3,700,000; white blood cells, 10,100; polymorphonuclears, 69 per cent. There were from one to three foul smelling, light brown and frothy stools a day; they contained no blood or parasites. The Wassermann test was negative. The blood was of Group II. Proctoscopic examination revealed a uniform, curdy, milklike film covering the mucosa, which was dry and shiny; there were no ulcerations; there were internal hemorrhoids.

October 1, 800 c.c. of blood were transfused without reaction.

October 6, the hemoglobin was 70 per cent.; red blood cells, 3,500,000. The patient had occasional attacks of nausea and vomiting.

October 30, he vomited. Examination of the vomitus revealed: free hydrochloric acid, 0; total acid, 24; guaiac test, negative. The sores of the mouth became worse.

October 31, hemoglobin was 63 per cent.; red blood cells, 2,600,000; no abnormalities of the red blood cells were noted.

November 17, in the evening, the patient vomited and complained of generalized abdominal pain. The abdomen was retracted and tense; deep pressure in every part gave pain, which was somewhat relieved later by a poultice.

November 18, 4:30 a. m., a stool of the usual appearance was passed; at 6 a. m., the patient vomited fluid with dark brown particles; at 6:30 a. m. he was in great distress. He said he had been in pain all night both from his abdomen and on account of contractures which had appeared in his extremities. On examination the patient presented the picture of tetany. The upper extremities were extremely spastic, drawn up and flexed at the elbows, flexed and rotated outward at the wrists. The fingers were flexed at the metacarpophalangeal joints, and the interphalangeal joints were extended. The lower extremities were also spastic, with flexion at the knees and extension at the ankles. The retraction and general tenderness of the abdomen, because there was no fever or localization of the pain, was looked on as an expression of a generalized state of muscular hypertonicity. The patient vomited again. Examination of the vomitus revealed free hydrochloric acid, 0; total acid, 0. Spasms of the extremities disappeared in the late morning. The temperature was between 98 and 99 F.; the pulse, from 70 to 90. The serum calcium was 8 mg. per hundred c.c. (normal, from 9 to 11 mg. per hundred c.c.). An infusion of 400 c.c. of a 0.2 per cent. calcium lactate solution was performed. Thirty minutes later the serum calcium was 8.3 mg. per hundred c.c.

November 19, hemoglobin was 70 per cent.; red blood cells, 3,000,000; polymorphonuclears, 68 per cent. The patient still had abdominal pain, but on account of the normal temperature and low pulse rate, no new abdominal complication was suspected. The serum calcium was 6.5 mg. per hundred c.c. An infusion of 400 c.c. of a 0.2 per cent. solution of calcium lactate was performed. Thirty minutes later the serum calcium was 6.5 mg. per hundred c.c. The patient had frequent involuntary stools during the day. The plasma carbon dioxid capacity was 57.6 per cent. by volume.

November 20, the temperature for the first time rose above normal (102 F.). The pulse was 130. Tetanic contractions reappeared. A transfusion of 400 c.c. of blood was performed. Thirty minutes later the serum calcium was 7.5 mg. per hundred c.c. An infusion of 350 c.c. of a 0.2 per cent. solution of calcium lactate was performed.

November 21, the temperature was 103.4 F.; pulse, 124. There was twitching of the extremities. An infusion of 800 c.c. of a 0.1 per cent. solution of calcium lactate in 0.4 per cent. saline was performed. The patient died.

During the last forty-eight hours, the patient vomited almost constantly except after lavage. The vomitus was first dark green, and later, dark brown. The fever which developed during the last twenty-four hours, by which time the abdomen had relaxed, was considered secondary to the constant vomiting.

The final diagnosis was: tetany; acute dilatation of the stomach, and sprue.

Summary of Postmortem Findings.—There were sprue (clinical); atrophic enteritis; atrophy of the papillae of the tongue, and general purulent peritonitis. The abdomen contained about 300 c.c. of dirty, yellow, purulent fluid. The intestines were matted together with yellowish fibrin and covered with a purulent exudate. The appendix was gangrenous, with rupture; it was hanging over the pelvic brim; in its middle it was necrotic and perforated. There was acute dilatation of the stomach and intestines; the stomach, the duodenum and 2 feet of the jejunum were hugely dilated with fluid and a little gas. The gastric musculature was not thickened; there were cardiac hypertrophy; chronic cardiac valvular disease (aortic valve), and generalized arteriosclerosis. The bone marrow was hypertrophic. The parathyroids were normal.

COMMENT

A diminished concentration of calcium in the blood has been shown to produce tetany, and in the case under discussion, the lack of this element was demonstrated by analysis of the blood. As bearing on the question of the cause of the disturbance of calcium metabolism in

this particular individual, the following points are emphasized:

1. According to von Noorden, calcium is absorbed in the upper part of the small intestine, combined with phosphoric and carbonic acids, but more especially with fatty acids in the form of soaps. Sprue patients, however, and many stool examinations proved it in this case, cannot readily digest fats. Is it not conceivable, then, that calcium was carried on with the fats, and that its absorption through the diseased intestinal mucosa was insufficient to maintain the proper balance? This is mentioned as a possible predisposing factor.

Calcium is mostly excreted into the large bowel; and in the present instance, owing to the prolonged intestinal irritation lasting over six or more years, the excretory rate of the substance by this outlet may have been abnormally increased. Such abnormal elimination would have tended to disturb still further the calcium equilibrium.

2. Clinically, tetany is occasionally associated with gastric dilatation, usually following pyloric obstruction and accompanied by considerable vomiting. We have produced pedal spasms in dogs by simply closing the pylorus with a ligature, and have found, as did McCann,[2] that an increased concentration of carbon dioxid bound as bicarbonate in the plasma, and a gradual diminution and final loss of free or combined hydrochloric acid in the gastric contents, resulted from this procedure. Gastric tetany is not known to be associated with a diminished calcium concentration in the blood, although calcium therapy relieves it.[3] Comparison with this case reveals certain similarities and decided differences as well. There was some vomiting, and at necropsy the stomach as well as the duodenum was found hugely dilated, but with no pyloric obstruction. A specimen of vomitus examined shortly after the onset of tetany showed that there was no acid present; however, in the presence of a patent pylorus this may well have been due to duodenal regurgitation. A Van Slyke carbon dioxid determination revealed no alkalosis (57.6 c.c.). Furthermore, there was an actual decrease in the calcium concentration of the serum unrelieved by calcium lactate infusions. These findings are

2. McCann, W. S.: J. Biol. Chem. **35**: 553 (Sept. 18) 1918.
3. Kinnicutt, F. P.: Am. J. M. Sc. **138**: 1, 1909.

opposed to the classification of this case as one of simple so-called "gastric tetany," even though the factors involved may have had some causal influences.

3. Tetany occurs as a rare complication of acute infectious diseases, but in this instance it seems far fetched to attribute any direct etiologic significance to the appendicitis and general peritonitis found at necropsy.

4. Calcium infusions can usually be counted on to abolish the seizures of tetany, but in this case there was no abatement, and the failure was mirrored in the blood analyses. It was a great surprise to find that injections of as much as 400 c.c. of a 0.2 per cent solution of calcium lactate, which theoretically should increase calcium to the extent of about 5 mg. per hundred c.c., had no such effect. Within thirty minutes after both infusions, the quantity of the calcium introduced had left the blood flowing through the peripheral circulation. Was the calcium excreted in that short period into the intestine, was the condition of the blood colloids such that the calcium present existed in saturated solution and any additional calcium was immediately precipitated, or was calcium immediately claimed by lime-starved tissue cells? That this is not the case in parathyroid tetany is shown by the following analyses, made at the same time as the foregoing determinations:

In a dog in acute tetany, the serum calcium was 5.1 mg. per hundred. Infusion of 40 c.c. of 1 per cent. calcium chlorid solution was followed by complete cessation of symptoms. The serum calcium, thirty minutes later, was 9 mg. per hundred.

That the condition of the blood was an important factor is suggested by the rise in calcium following the transfusion of normal blood. We consider some of these points suggestive, but not conclusive enough to form any hypothesis for explaining the course of events which led up to the state of tetany.

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N. S., Vol. XIX, Nos. 1–5, January–May, 1918.]

TWO UNUSUAL CASES OF MELANOCARCINOMA

H. A. MURRAY, M.D.

(From the Department of Surgery, College of Physicians and Surgeons, Columbia University, New York)

I shall present the histories and pathological specimens of two cases of malignant neoplasm of the same type, the characteristics of which are sufficiently distinct, we believe, to make the diagnosis unmistakable.

Malignant melanomas are not uncommon and we would not have considered these cases worth recording if it were not for the fact that their clinical appearance was unusual enough to puzzle a number of capable surgeons who remained ignorant of the true nature of the tumors until the pathological reports were made known. Believing that on this account they will be of some interest to the society, I offer the following cases for your consideration:

CASE I.—No. 64383. Mrs. D., housewife, aged 35 years, entered the Presbyterian Hospital on October 29, 1918, complaining of a tumor of the right lateral costal region of six years' duration.

Present Illness: The patient says that she has always had a small brown mole at the site of the present tumor. Six years ago this was tied off and later for some reason treated with cocaine, leaving a brownish speck in a small scar which spread slightly but gave no trouble until three years later. At this time the mole became irritated and broke open with some bleeding. After healing a small lump remained. Twenty-one months ago at the end of her third pregnancy, the lump again became irritated and broke open. Since that time it has grown rather rapidly in size, especially in the last two months, and there has been a persistent reddish-yellow discharge.

She complains of continuous dull pain in the tumor and frequent shooting pains radiating from the axilla around the side to the site of the mass. The pain is increased by using the right arm, which feels numb. For the past three months she has noticed swollen glands which have grown rapidly in the right armpit and right side of neck. Lately she has lost some weight and strength.

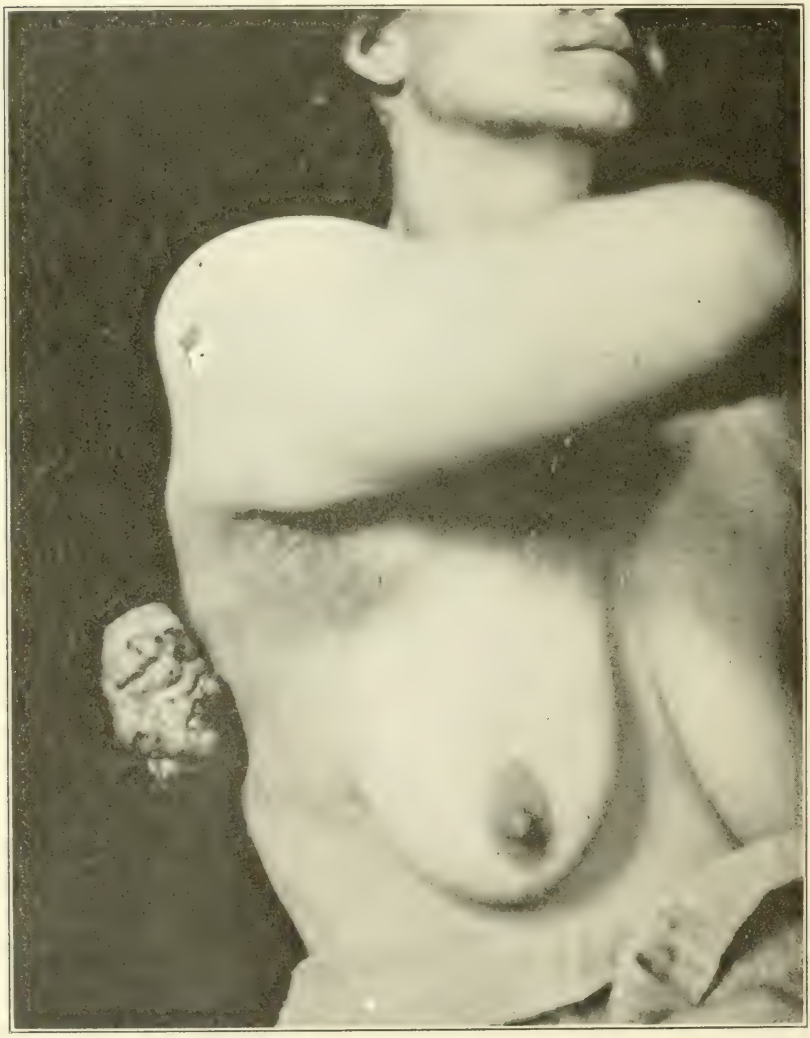

FIG. 1. Case I. Presbyterian Hospital No. 6781. Pedunculated melanocarcinoma at the time of entrance into the hospital.

Past History: Aside from an operation for appendicitis fourteen years ago, she has never been sick. She has had three pregnancies; a stillbirth and two living children who are now in good health.

Family History: Negative.

Physical Examination: In the right lateral costal region is a cauliflower-like tumor (Fig. 1), six inches in diameter, attached to the skin by a small pedicle, around the margins of which in the skin are several nodules of varying size. The surface of the mass is necrotic and discharges a greenish-black foul-smelling exudate. No other moles are found elsewhere in the skin.

In the right axilla and right supra-clavicular regions there are masses of hard glands. There were râles in both lungs.

Diagnosis: "Probably sarcoma of the chest wall."

Course: Dr. Hawkes, the surgeon in charge, decided to remove the primary growth as a palliative measure.

Operation: Oct. 30, 1918. An elliptical incision around the tumor about two inches away from the pedicle was made so as to include the few surrounding nodes in the skin. A plain gauze drain was inserted in the outer end of the wound which was closed with silkworm gut and silk.

After the operation, the axillary glands grew rapidly, causing much discomfort from their size and so a second operation was decided upon.

Pre-operative diagnosis was metastatic sarcoma of axillary glands.

Operation: November 14, 1918. A six-inch incision parallel to the lower edge of the right pectoralis major muscle gave sufficient space for the removal of a dense mass of lymph nodes and adherent connective tissue, the whole thoroughly infiltrated by neoplasm. The operation was of necessity incomplete due to the invasion of chest wall structure by tumor tissue. A gauze drain was inserted in the upper, outer corner of the wound.

X-ray examination on October 29 had shown the presence of nodules in the left lung and so the patient was subjected to twelve x-ray treatments at about five-day intervals, covering the chest anteriorly and posteriorly on both sides. Coley's serum was injected three times, in doses of ⅛–½ minims at about four-day intervals.

The wound from the second operation healed rather quickly, but the posterior wound was slow to repair and a number of small tumor nodules developed in the surrounding skin. Throughout her stay in the hospital the woman ran a morning temperature of 100° to 101° until the last two weeks when it occasionally reached 103°. The pulse varied between 80 and 120.

The left axillary nodes, the right side of the tongue, the left inguinal nodes and the right cervical glands then became involved. One hundred milligrams of radium were applied for one hour on two occasions to the tongue with no improvement.

On January 13 the patient had convulsions which left her with facial paralysis and ptosis of both upper lids, and on January 17, after a series of spasmodic twitchings in all her muscles, she died. The immediate cause of death was thought to have been one or more metastases in the brain. Permission for autopsy was not obtained.

First Pathological Report, October 30, 1918:

Gross Examination: The specimen consists of an elliptical piece of skin, 7 × 5 cm., attached by a pedicle 2.5 cm. wide, to a lobulated dense tumor mass, 17 × 15 × 9 cm. (Fig. 2). In spots the surface is ulcerated. On one

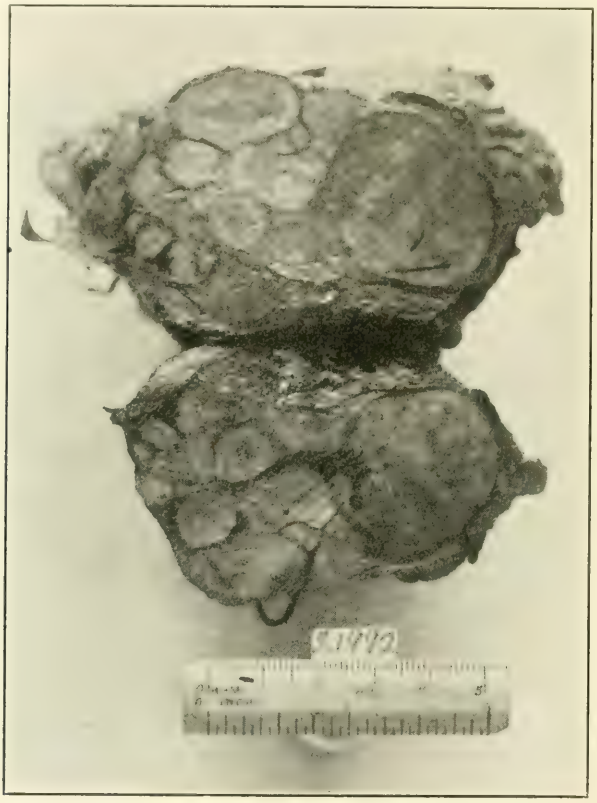

FIG. 2. Case I. Cut section of the tumor.

side the lobulations are small, 0.2 cm. in diameter, but elsewhere they are about 2 cm. in diameter, and their respective stems connect with the main pedicle. The cut section shows an irregular cortex of white tumor tissue conforming to the lobulations on the surface. In the depths of the stroma and actually in the pedicle there are four rounded distinct tumor masses apparently separated from the pedunculated surface lobulations.

Microscopic Examination: The tumor mass is divided by very vascular connective tissue into lobules which are further subdivided into alveoli (Fig. 3). These are filled with great numbers of large, sharply outlined irregularly shaped cells of various types. Most of them are round, but there are many others which are fusiform, hexagonal and rectangular in outline. The nuclei

are as a rule large and vesicular, but otherwise present all varieties of shapes and positions in a homogeneous pink cytoplasm. Many cells have more than one nucleus—as many as ten being found in one cell. In some cases the cytoplasm of the various cells appears as one homogeneous matrix, whereas in

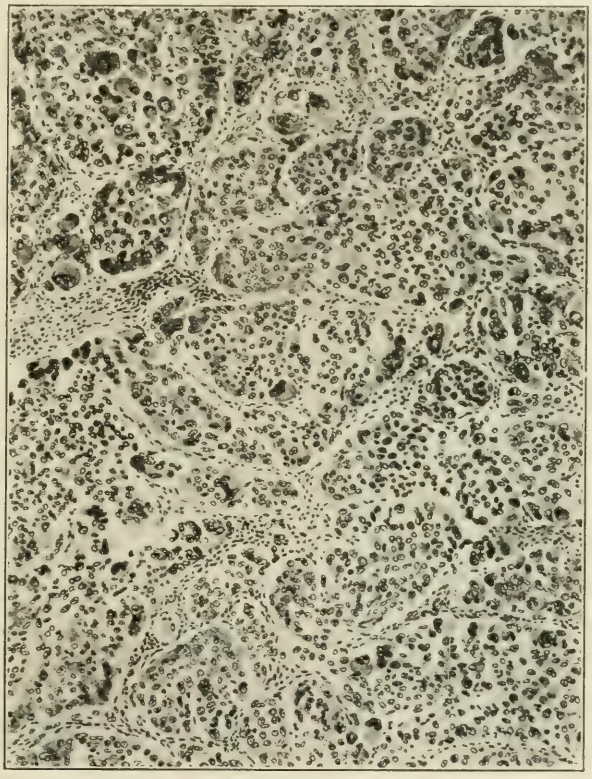

FIG. 3. Case I. Microscopic view of the tumor showing general alveolar configuration.

other parts there are definite margins between the cells which have distinctly epithelial characteristics. Vacuoles are common. There are numerous mitoses, and the picture is clearly one of intensive cellular proliferation. There are areas of hemorrhage and round cell infiltration.

Diagnosis: Sarcoma of the skin of the lateral costal region.

(N.B. It was not noticed until later that in certain areas there were numerous large non-phagocytic cells filled with brown granular pigment which had the characteristic appearance of melanin.)

Second Pathological Report, November 14, 1918:

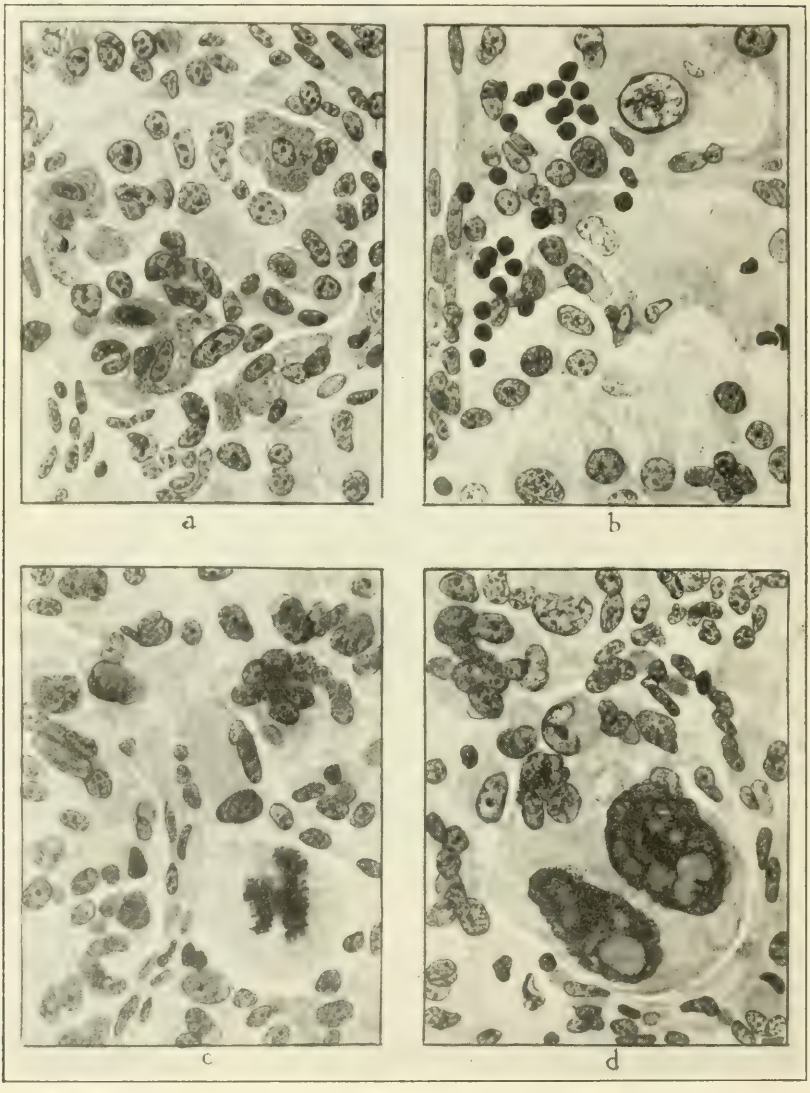

FIG. 4. Case I. High-power view of different areas of the tumor. (*a*) Melanin-containing cells, (*b*) hyalin ground substance, (*c*) mitosis, (*d*) giant cells.

Gross Examination: Specimen consists of a polygonal mass, 10 × 7 × 6 cm. Its outer surface is everywhere roughened where the wound of operation has separated the tumor mass from the surrounding tissue. There are several prominent, irregularly rounded elevations suggesting an internal lobulation. On cut section, there is found to be an adventitious capsule averaging about 0.75 cm. in thickness, within which there are rounded tumor masses distinct from the fibrous tissue. One of these masses is discolored, apparently from extravasated blood. In general, the tumor tissue is light in color where it is well preserved, but where degeneration has apparently commenced, it has a grayish tinge.

Microscopical Examination: There is an exceedingly loose reticular tissue structure supporting many large sized cells with relatively large, deeply staining nuclei (Fig. 4). Many of these cells have more than one nucleus. All the true tumor cells vary in size, as do also the nuclei within them. In places the tumor cells appear to be formed as if they were syncytial masses. There are scattered areas of hemorrhage and areas of degeneration. There are a few blood vessels of small size with relatively thin walls. A few small areas of lymphoid tissue suggest that the growth has taken the place of a lymph node.

Diagnosis: Metastatic sarcoma of the skin in the axillary lymph glands.

(No pigment-containing cells were found in any of the slides from the axilla.)

After Dr. Mallory had seen the slides and made a diagnosis of melanosarcoma and a number of differential stains had been made to exclude the possibility of the presence of neuroglia fibers, the diagnosis of melanocarcinoma of the skin of the lateral costal region was made by Dr. Clarke.

Case II. No. 15523, D. C., a tug-boat captain, aged 68 years, entered the Vanderbilt Clinic on March 7, 1919, complaining of a growth of the lower mid-dorsal region. Duration—one year.

Present Illness: The patient says that ever since he can remember he had a small, flat, brown mole about 0.5 × 0.75 inches over his lumbar vertebræ. About one year ago it became irritated by his clothing and started to increase in size, until now it is about three inches in diameter. Growth has not been at a steady rate, but has varied, so that at times it has progressed more rapidly than at others. During the last four months there has been an almost continuous watery discharge, often hemorrhagic, which each day soaked through three thick layers of gauze. The tumor is only painful when it is mechanically irritated. The man has had a feeling of heat along the inner side of his right leg during the last few days. He says that he has lost a little weight and strength lately due to anxiety about his condition.

Past History: Negative.

Family History: Negative.

Physical Examination: In the mid-dorsal region, just to the right of the third lumbar vertebra is a lobulated, pedunculated tumor, 7 × 9 cm., elevated about 4 cm. from the skin surface. It is mostly pinkish in color, but is marked with many ulcerating and hemorrhagic areas of various shades of green, red and black. The skin immediately surrounding the growth has a

sort of pinkish color. There are many other widely distributed, pigmented moles, some flat and others elevated, in the skin. The main claims that these have existed since childhood.

A rather hurried general examination of the chest and the abdomen was negative. No lymph nodes were found to be enlarged.

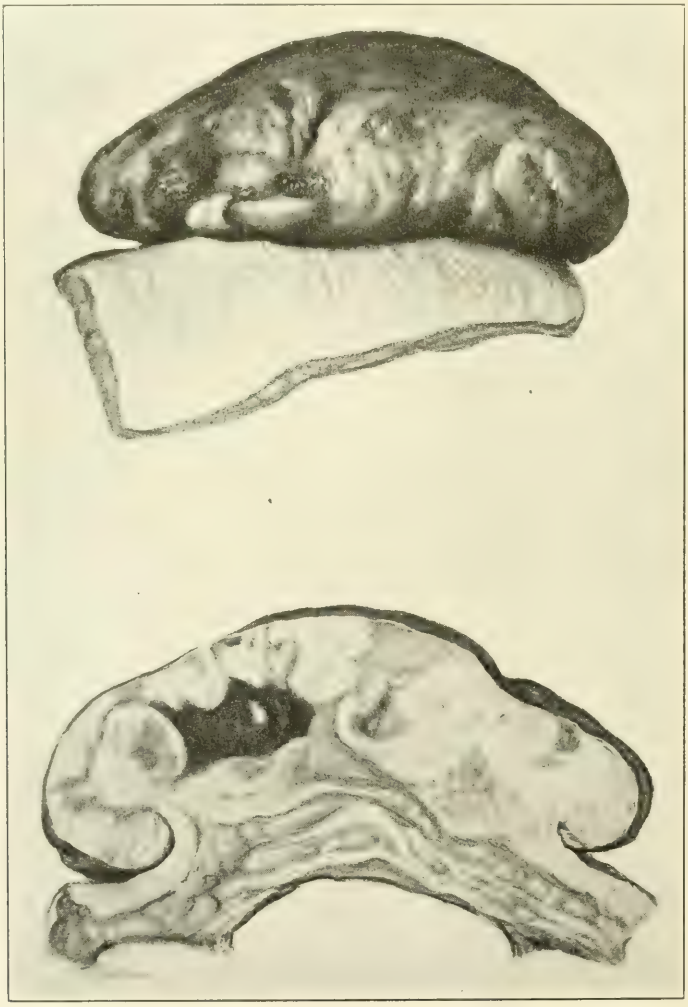

FIG. 5. Case II. Vanderbilt Clinic, No. 15523, Surgical Pathology No. 5410. Cut section of the melano-carcinoma of the skin of the back removed at operation.

Diagnosis: Fibro-epithelial tumor of the skin.

Operation: March 7, 1919. Dr. Loewi removed the tumor by an elliptical incision through the skin, which included some subcutaneous tissue.

Course: The wound is healing as well as can be expected.

X-ray shows an enlarged thoracic aorta and an apparent rarefaction or twisting of the fifth lumbar vertebra, but no suggestive evidence of any metastases.

Pathological Report

Gross Examination: From an irregular area of skin and subcutaneous tissue, 10×7 cm., there protrudes a mushroom-like tumor mass, $7 \times 7 \times 2$ cm. (Fig. 5). The pedicle is 4 cm. in diameter. The surface of the growth is rough and lobulated, overhangs the edges, and except for two widely-separated areas, is excoriated and free from epithelium. On cut section, the skin and subcutaneous tissue is about 1 cm. in thickness and is distinct from the tumor proper, which consists of rounded, irregular masses of solid and relatively homogeneous neoplastic tissue. There are some dark areas, apparently due to hemorrhage, one of which is about 0.5×1 cm. Gross examination suggests a very cellular type of tumor growth.

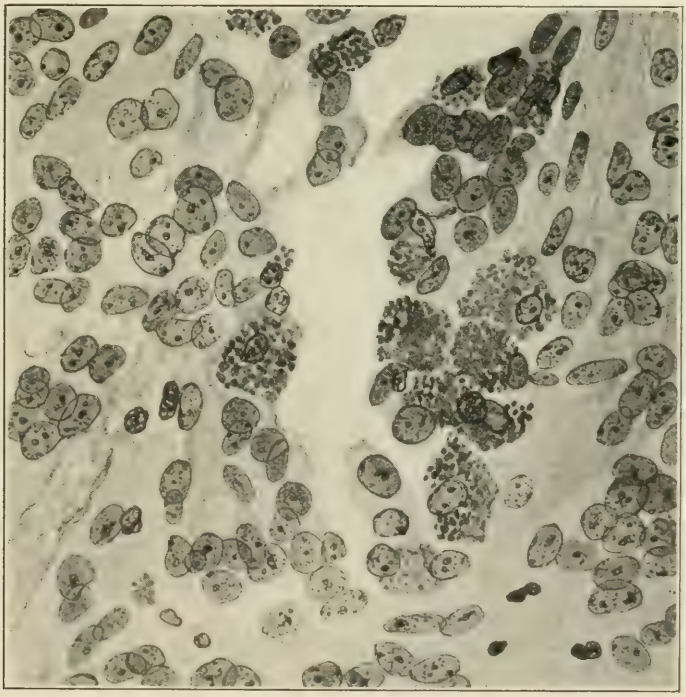

FIG. 6. Case II. Microscopic view of the tumor showing melanin-containing cells.

Microscopic Examination: The section shows that the tumor is composed of a great number of cells closely packed together and divided irregularly by fine connective tissue trabeculæ into alveoli of varying shapes and sizes (Fig. 6). In general the cells have little appreciable cytoplasm, but consist mostly of relatively large oval vesicular nuclei. There are other cells, however, with considerable protoplasm and some with smaller pycnotic nuclei. Numerous pigment-containing cells are found throughout the section; some of these, situated in the trabeculæ, have rather large, light-brown refractile granules which by the potassium ferrocyanide stain are shown to contain iron; whereas others, *i.e.*, the true tumor cells in the alveoli—contain smaller and darker granules which are not differentially stained and have the typical appearance of melanin.

Diagnosis: By Dr. Clarke: Melano-carcinoma of the skin.

In the first case discussed, as the result of a routine morphological examination by the pathologists, who were not aware that the growth originated in a mole, the diagnosis of sarcoma was given. It was not until a second more careful microscopical examination was made that the pigment cells were observed, and in fact these were so few in number that it is perfectly conceivable that sections might have been cut in which there would have been none of them present. There are many such instances in which morphology alone cannot be relied upon in all cases to give the most accurate interpretation of a disease process. In the second case the similarity between it and the previous one was immediately recognized and the diagnosis given on gross examination was made more certain by the knowledge that the growth originated from a mole.

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A TUMOR OF THE ULNAR NERVE

A. P. STOUT, M.D.

Recently there has been a great deal of interest evinced in tumors arising from the various derivatives of the neural ectoderm. Marchand,[1] Wright,[2] Martius[3] and a number of other observers have described tumors arising from the neurocytes or neuroblasts of the sympathetic and cerebrospinal system; and these tumors are now very generally known under the names malignant neuroblastoma, neurocytoma, ganglioneuroma and chromaffin tumors.[4, 5, 6]. All these cells are the more or less undifferentiated forerunners of the true nerve cells of the sympathetic and cerebrospinal system.

The nerve cells, however, are not the only derivatives of the neuroectoderm. Certain of the smaller cells of the neural crest develop into the so-called "indifferent cells" or "supporting cells" and these in turn form in the brain and cord the neuroglia and ependyma cells; in the spinal ganglia, the amphicytes, and in the peripheral nerves, the lemmocytes which develop into the neurilemma or sheath of Schwann cells.

The origin of the neurilemma cells is still a matter of debate, since, according to one view, they are of mesodermal origin. The majority of neural anatomists, however, believe that certain of the smaller cells in the neural crest instead of becoming nerve cells wander out along the nerve fibers and become the neurilemma cells. This view is strongly supported by the work of Harrison,[7] who found that in certain types the removal of the neural crest resulted in the formation of efferent nerves without neurilemma cells. If this view is accepted, the neurilemma cells must be considered strictly comparable to the neuroglia cells of the neural tube.

The gliomata, or tumors arising from neuroglia cells, are found only in the brain and cord, along the course of certain cerebral nerves, and in the retina. In certain of the retinal gliomata there occurs a concentric grouping of cells about a central

lumen or cavity which is accentuated by a circular membrane which lies at a short distance internal to the innermost layer of tumor cells. Flexner[8] and Wintersteiner[9] believed that these so-called "rosettes" represented cells from the layer of rods and cones, and that the tumor should be called a neuroepithelioma. This view is still supported by some, notably MacCallum[10] and Mallory.[11] Pusey,[12] however, used Mallory's stain and demonstrated that glia fibrils extended from the cells surrounding the rosette to the edge of the lumen forming there a distinct circular ring and sometimes passing beyond this into the lumen. An appearance somewhat similar to this is found in the ependymal gliomata when the ependymal cells form pseudoglandular structures which Mallory[11] has shown to be formed of ependymal cells.

In passing it may be noted that these rosettes differ from those described as characteristic of the neuroblastomata, in that the latter are small concentric aggregations of cells separated from surrounding cell groups by a considerable amount of fibrillar ground substance. The fibers of this ground substance and the fibers forming the center of the rosette take a stain which is characteristic neither of collagen nor of neuroglia. Küster[13] described two tumors of the adrenal medulla with rosettes in them which he and Ribbert believed were similar to the gliomata of the brain and they called the tumors gliomata. These rosettes, however, are, as his drawings show, similar to the formative sympathetic cell clusters and Wiesel[14] recognized this fact. Since that time, authors generally have considered Küster's cases as malignant neuroblastomata. It is hard to imagine how neuroglia could be found in the adrenal medulla.

If the literature dealing with the tumors of the Gasserian ganglian is considered, it appears that Marchand,[1] in discussing the possible sources of origin for his tumor, suggested that it might have come from the cells forming the sheath of Schwann, but finally decided that it was a neurocytoma, or tumor arising from the undifferentiated cells of the central nervous system. Sachs,[15] Spiller,[16] and Dercum, Keen, and Spiller[17] have re-

ported cases which they believed resembled Marchand's cases. Sachs has some good photomicrographs which show that the tumor is composed of solid strands of epithelial-like cells separated by thick strands of connective tissue. Here and there are rounded holes among the tumor cells with a distinct membrane about them. On this account Sachs thought the tumor ought to be called an endothelioma. It is interesting to note that this case and that of Dercum, Keen, and Spiller were malignant tumors metastasizing in the cervical lymph-nodes. None of these investigators used the Mallory stain.

Turning now to tumors arising in the peripheral nerves, one is impressed with the fact that the literature is very scanty, but the majority of authors consulted seem to agree that whether single or multiple, malignant or benign, they are of mesodermal origin coming from the epineural or perineural tissue. Some of them have in addition an overgrowth of nerve fibers.[18, 19, 20] In 1908, on the other hand, Verocay[21] described a case with multiple tumors of the nervous system which showed in many of the nodules in the peripheral nerves what he believed to be a marked growth of cells of the sheath of Schwann. He, thus, is the first author to suggest that the neurilemma cells may be the source of tumors of the peripheral nerves. This view is looked upon with favor by Borst.[22]

In this connection the result of sectioning peripheral nerves is of great interest. Tinel,[23] in a book on Nerve Wounds, which has just appeared, makes the following statement: If a peripheral nerve be sectioned there appears on the central end the classical amputation neuroma. This is composed of tangled nerve fibrils embedded in fibrous tissue which is sprinkled with numerous cells resulting from the proliferation of the cells of the sheath of Schwann. The peripheral end presents a swelling which is composed solely of the excessive proliferation of the cells of the sheath of Schwann. This Nageotte calls a false neuroma or glioma. It is of course not a true neoplasm but a hyperplasia, and is comparable to that which occurs in hyperplasia of scar tissue or false keloid.

The tumor under consideration started nine months before operation as a swelling on the anterior aspect of the right forearm of a male Italian laborer, forty-two years old, who was otherwise apparently well. One and one half months after its appearance he noticed a mass in the axilla on the same side. There was only partial interference with the function of the ulnar nerve noted.

Interscapulo-thoracic amputation was performed by Dr. A. V. S. Lambert, on November 20, 1917. Examination of the arm showed a fusiform tumor occupying the course of the ulnar nerve, apparently starting within its sheath at that point in the palm of the hand where the nerve splits up into its terminal branches, and extending to a point just below the internal epicondyle of the humerus. The tumor was circumscribed and was dissected away from the surrounding muscles only with difficulty. At its thickest point it was adherent to the skin, which was ulcerated. In the axilla was one large mass of the same appearance and consistency as the nerve tumor, measuring $15 \times 14 \times 0.5$ cm., through which passed the great axillary vessels and nerves, some of the intercostal nerves, and the long thoracic nerve. Adjacent to this were numerous rounded nodules from 1 to 2 cm. in diameter which appeared, some in the surrounding muscles, one, at least, in the course of the long thoracic nerve; and others were found at operation in the supraclavicular fossa. These masses have three possible explanations: (1) they may be metastases in lymph glands: (2) they may be direct extensions along the nerve trunk; (3) they may be independent tumors, since tumors of the peripheral nerves are often multiple. The material has not yet been sufficiently studied to determine which is the correct hypothesis. Personally I believe them to be metastases.

The microscopic morphology of the tumor is everywhere the same and is distinctive. There are thick masses and strands of rather small rounded cells, many of which show mitoses, separated by trabeculæ of connective tissue. Scattered through the tumor cells at irregular intervals are many rosettes which closely resemble those described as being found in the retinal gliomata.

These are small circular holes surrounded by a sharply outlined membrane which is red with a Mallory stain. Passing from the membrane between the surrounding cells like the rays of a star are many fine fibrils which in some instances pass over the membrane and are seen in the lumen of the rosette.[1] These are also red with a Mallory stain. The fact that these fibers stain red with a Mallory stain of course does not *prove* them to be akin to neuroglia, since Mallory has shown that not only neuroglia but also fibroglia, myoglia, and fibrin stain red as well.

The close resemblance between this tumor and some of those described as arising from the Gasserian ganglion must also now be apparent. Both are malignant, metastasizing at a distance, and in their microscopic appearance they have many points in common. It is of course possible that this tumor, like Marchand's, may have arisen from neurocytes, since ganglion cells have been found in the course of some of the peripheral nerves.[24, 25] But this is an exceedingly rare occurrence and it is much easier to believe that it arose from neurilemma cells which are constantly present in all efferent peripheral nerves. It is also possible that Marchand may have been nearer the truth in his discarded hypothesis, that his tumor arose from the cells of the sheath of Schwann.

In conclusion, it may be said that the tumor under consideration is a malignant neoplasm. Grossly it resembles the sarcomata, and microscopically and tinctorially it has some points in resemblance to the retinal gliomata and to some of the Gasserian ganglion tumors. Since the neurilemma of the peripheral cells is probably homologous to the neuroglia of the central nervous system, it is suggested that this tumor may be a neoplasm arising from neurilemma cells or lemmocytes.

I wish here to thank Dr. A. V. S. Lambert for his permission to report this case.

Case History

J. T.; 42 years; male; Italian; laborer; married; admitted to the Presbyterian Hospital November 15, 1917.

Chief complaint; lump in right arm. Present history: Nine months ago first noticed a numbness of the anterior surface of the little finger. Soon

after appeared a swelling of the anterior surface of the forearm which was hard and not tender. One and one half months later a lump appeared in the right axilla which was at times very painful. Two months before admission, a cut was made into the mass in the forearm. After this the masses in the forearm and axilla increased rapidly in size and the pain grew very great.

Past and Family History: Neisser infection, twenty-one years ago. Wife had seven miscarriages. Otherwise negative.

Physical Examination: On the volar surface of the right forearm there is a mass which extends from just below the bend of the elbow to just above the wrist. At the lower end it is raised above the skin about 2 cm. and its surface is ulcerated. The mass is firm, slightly tender, nodular, and seems to be attached to the muscle but not to the bone, as it moves freely from side

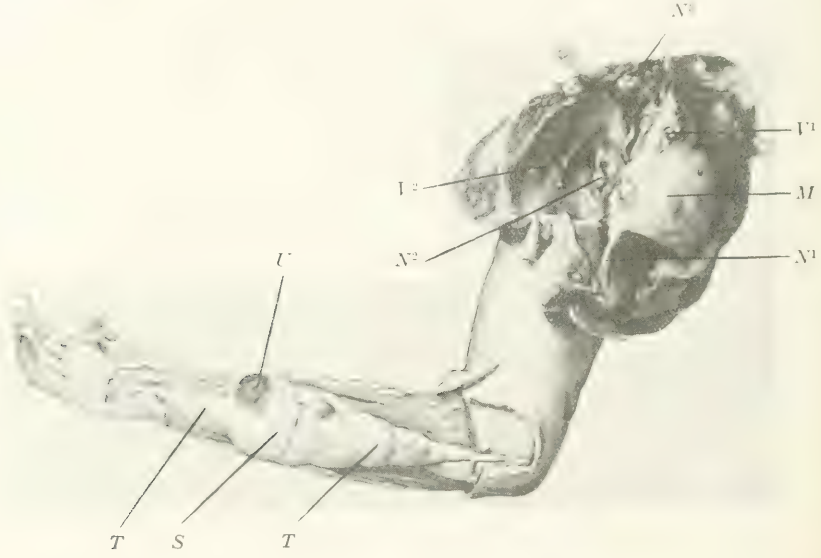

FIG. 1. Photograph of sketch of dissected upper extremity. *T T*, tumor occupying course of ulnar nerve; *U*, ulcerated surface of tumor; *S*, area of skin infiltrated by tumor tissue; *M*, large axillary mass dissected and reflected back from its bed; V^1, great vessels and nerves passing through top of mass (cut and reflected with mass); V^2, the peripheral ends of great vessels and nerves at the bottom of the cavity from which the mass *M* was reflected; N^1, nodule in course of long thoracic nerve; N^2, nodule in substance of subscapularis muscle; N^3, another axillary nodule.

to side. The intrinsic hand muscles show considerable atrophy. In the axilla is a mass, three by four inches, with irregular surface, not tender, and freely movable from side to side. Above the clavicle can be felt some three or four small masses from 0.5 to 1.5 cm. in diameter. In the epitrochlear region can be felt other nodes. Sensation over the ulnar distribution is diminished over the right side.

The lungs show bronchovesicular breathing symmetrically over both chests. No rales. Physical signs were otherwise negative.

Wassermann reaction was negative.

Operation: November 20, 1917, by Dr. A. V. S. Lambert. Interscapulothoracic amputation of right upper extremity

Post-operative Course: The wound healed promptly and the patient was discharged December 7, 1917, seventeen days after operation, at which time

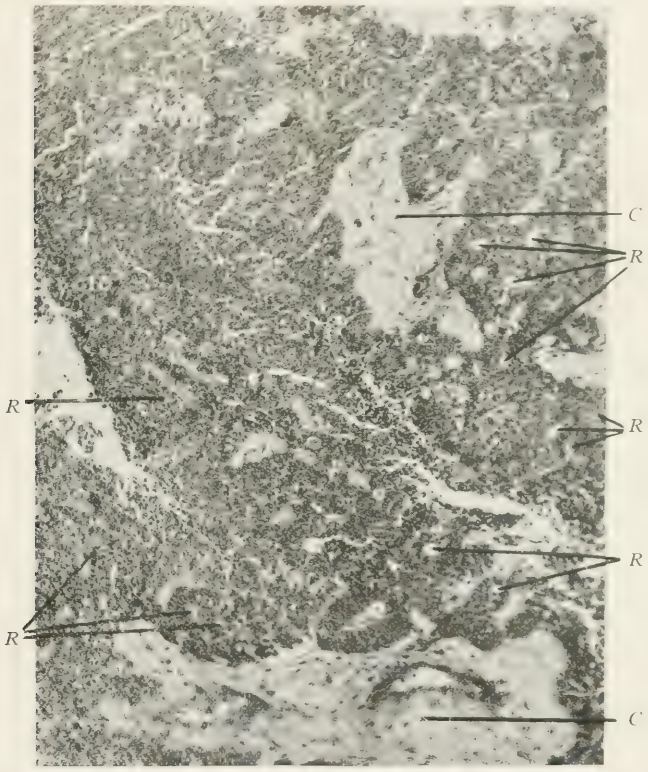

FIG. 2. Hematoxylin and eosin stain. Medium magnification microphotograph of typical field of tumor. There are many rosettes and trabeculæ of connective tissue. (*R*, rosette; *C*, connective tissue trabeculæ.) Only the most prominent ones are indicated.

there was felt an indefinite mass in the neck apparently above the nerve stumps of the brachial plexus. This was thought to be a recurrence.

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Gross Specimen: Specimen consists of a right arm, including the shoulder joint, scapula, and half of the clavicle (Fig. 1). Presenting on the internal

anterior aspect of the forearm is a large nodular swelling adherent to the skin, on the highest point of which is a recent operative wound surrounded by an area of ulceration. On dissecting the forearm, it is seen that this mass is part of a fusiform, nodular, firm, white tumor mass which starts apparently within the sheath of the ulnar nerve just below the internal epicondyle of the humerus, grows gradually thicker until it is 6.5 cm. in diameter at the junc-

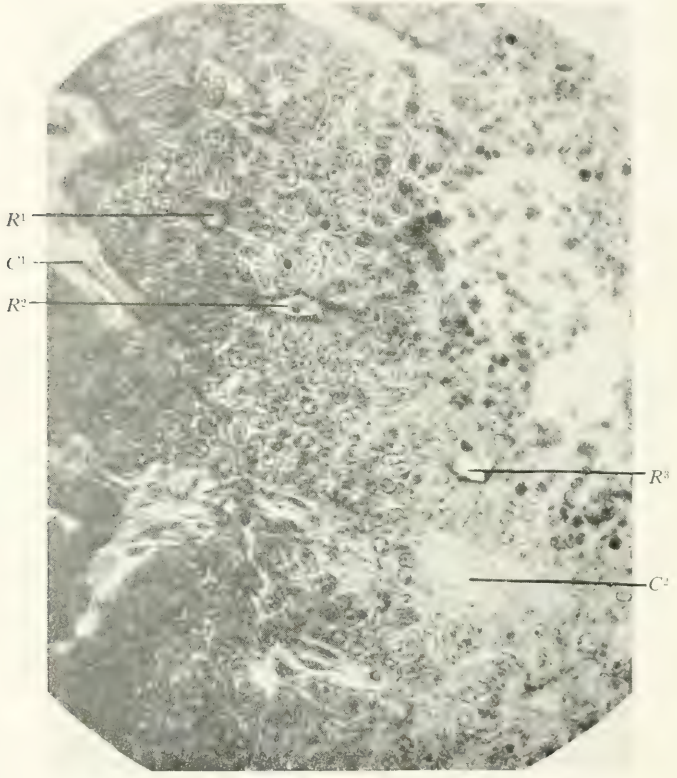

FIG. 3. Mallory stain. High power microphotograph of 3 rosettes, R^1, R^2, R^3, showing deeply stained membrane or rim from which radiates the fine fibrils between the surrounding cells. C^1 and C^2 are trabeculæ of connective tissue.

tion of the lower and middle thirds of the forearm, then rapidly diminishes in diameter until it ends as it began within the sheath of the ulnar nerve just below the annular ligament of the hand. It does not come into contact with bone at any point, but lies in front of and internal to the radius, ulna, and interosseous ligament.

In the axilla extending from the subclavian artery downward for a dis-

tance of 15 cm. along the lateral thoracic wall is a firm, white, nodular mass adherent to the surrounding structures and measuring 5 cm. at its thickest points. All the great vessels and nerves of the axilla and many of the intercostal nerves and vessels and the long thoracic nerve pass through it. The long thoracic nerve after it leaves the mass and splits to pass into the muscle, has a nodule apparently of tumor tissue about 1 cm. in diameter, either attached to or incorporated within the nerve sheath. In close proximity to

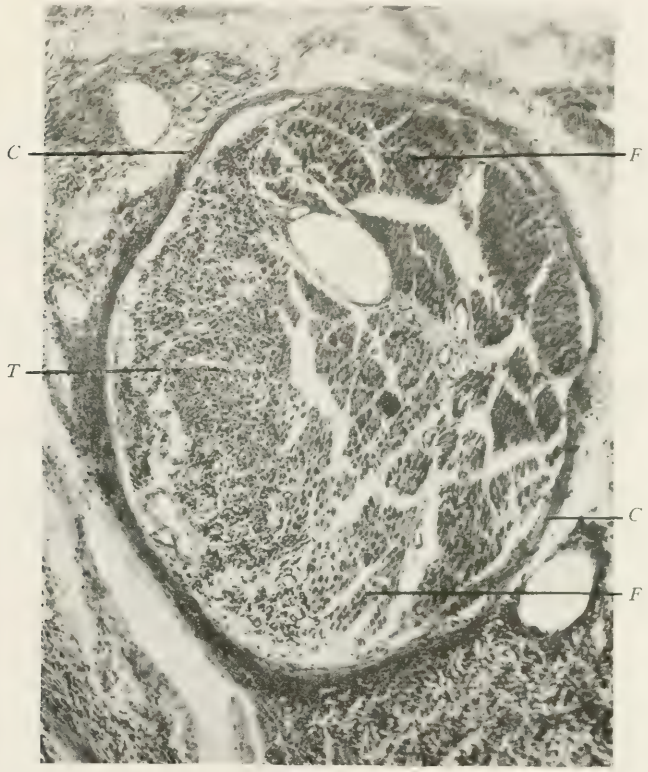

FIG. 4. Photomicrograph of section of tumor taken just below internal epicondyle of humerus. A bundle of nerve fibers in its connective tissue capsule (*c*) is shown with a mass of tumor cells (*t*) sharing the space and in intimate relationship with the bundles of nerve fibrils (*f*). Note large size and hyperplasia of the neurilemma cells.

the large mass are a number of small nodules from 1 to 2 cm. in diameter, some of which are superficial to it; others are deep and buried in the substance of the subscapularis muscle; while still others are found above it both in the axillary fat and in the supraclavicular fossa.

Microscopic Examination: Sections from the mass in the ulnar nerve and the axillary mass show the following architecture: The tumor cells are small, rounded, and of relatively uniform size; the nucleus is relatively large and takes a deep stain with hematoxylin (Fig. 2). There are numerous mitotic figures. The cells are massed, with an alveolar structure separated by thick trabeculæ of connective tissue bearing the blood vessels. Among the tumor cells are many small rounded spaces, some empty and others apparently filled with delicate tangled fibrils. With Mallory's aniline blue-orange G stain, these holes are sharply outlined by a deep red staining membrane from which numerous fine fibrils pass out in a radiating manner like the rays of a star between the surrounding tumor cells (Fig. 3); some of these at least seem to pass inwards into the lumen. With Van Gieson's nerve stain, these fibrils are not nearly as sharply defined. They have a tint which is almost like the red of the collagen fibrils but with a suggestion of orange in it. The tumor cells surround and are separated from the membrane by a space about the width of the nucleus which is filled up with these fibrils. A section taken from the tumor at a point just below the bend of the elbow where it measures only 1.5 cm. in thickness shows about the periphery of the mass of tumor cells some bundles of nerve fibers (Fig. 4). The neurilemma nuclei appear unusually prominent, and within one fasciculus there is seen a strand of tumor tissue in intimate relationship with the nerve fibers. Another fasciculus appears flattened out and compressed.

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